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Insects of Eastern Forests

INSECTS OF EASTERN FORESTS

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Highlights the description and biology of numerous species of harmful and useful insects found in forests and forest products east of the 100th meridian. This manual provides the forest practitioner and others with the means for identifying these insects and their related organisms.

KEYWORDS: damaging arthropods of America north of Mexico; entomological manual; forest pests in the United States; sap feeders, wood borers, bark beetles, and defoliators in North America; tree and wood-product pests.

Contents

Acknowledgments

Arnold T. Drooz, principal research entomologist, Southeastern Forest Experiment Station, Asheville, N.C., edited and coordinated materials from a team of specialists, who called upon others as needed. The original intent was to use as much of W. L. Baker's "Eastern Forest Insects" as possible, making only a minimum of changes. This proved impractical, as a number of specialists suggested that major up-dating was needed. These requests were allowed.

Only a few members of the team are qualified taxonomists. Therefore, the text was submitted to systematists in the U.S. Department of Agriculture and Smithsonian Institution for verification of the scientific names. Warm and grateful thanks and appreciation are due all of these people and their organizations for providing their time, expertise, and valuable suggestions toward completing this volume.

The names, organizations, and contribution of each member of this team are listed to cordially recognize their help. The following specialists revised and rewrote the subject matter of the text that follows their names:

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Connecticut Agricultural Experiment Station, New Haven
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There have been numerous changes in nomenclature since the earlier publications were printed, and keeping up with these changes is a never-ending process. Edna M. Hoover (retired) of the U.S. Department of Agriculture, ARS, Systematic Entomology Laboratory (SEL) at Beltsville, Md., transmitted the manuscript to various SEL and other specialists for verification of scientific names. She also verified some names when no specialist was available and assembled and transmitted the corrected texts. Her interest and devotion to this chore are greatly appreciated. The following list acknowledges the invaluable help of the SEL systematists at

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D. M. Anderson—Scolytidae
E. W. Baker—Acari
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R. W. Carlson—Ichneumonidae, Evaniidae
D. C. Ferguson—Nymphalidae, Papilionidae, Hesperiidae, Sphingidae, Geometridae, Lymantriidae, Lasiocampidae, Mimallonidae, Pyralidae, Phycitinae
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R. D. Gordon—Staphylinindae, Passalidae, Lucanidae, Scarabaeidae, Meliodae, Coccinellidae
E. E. Grissell—Chalcidoidea
A. B. Gurney, resident cooperating scientist—Orthoptera
J. L. Herring—Hemiptera except Tingidae
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D. R. Smith—Symphyta and Formicidae
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E. L. Todd—Ctenuchidae, Arctiidae, Noctuidae, Notodontidae,
R. E. White—Chrysomelidae, Cleridae, Anobiidae, Anthribidae, Brentidae
D. R. Whitehead—Rhyncophora
W. W. Wirth—Xylophagidae, Stratiomyidae, Rhagionidae

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Preface

The focus of "Insects of Eastern Forests" is primarily on insect pests of trees and wood products east of 100° longitude, north of Mexico. In a similar manner, the region west of this meridian is treated in "Western Forest Insects," by R. L. Furniss and V. M. Carolin, published in 1977 (U.S. Department of Agriculture Miscellaneous Publication No. 1339) *(457)*. Although the information included in these books is directed to professional foresters and forest entomologists, others in related fields and students should find them valuable references.

Insects are not alone in causing damage to trees and wood products. Therefore, it is important to include other small animals such as certain mites and mollusks that also injure trees and their products. Common arthropod pests that are found in the forest environment are mentioned briefly. Many kinds of insects and related arthropods are beneficial because they suppress populations of damaging species, so this book also includes information on these groups.

The original treatment of this subject was given in F. C. Craighead's "Insect Enemies of Eastern Forests" (U.S. Department of Agriculture Miscellaneous Publication 657), published in 1950 *(261)*. This valuable handbook was written in the late 1930's but publication was halted by the wartime emergency. When it finally was made available, DDT was the most promising development for the control of many forest pests, and a small amount of information on this "wonder chemical" was fitted into the text. By the time W. L. Baker's "Eastern Forest Insects" (U.S. Department of Agriculture Miscellaneous Publication 1175) was published in 1972 *(45)*, DDT was no longer permitted for agricultural and forestry purposes. Emphasis shifted from long-lived insecticides to those whose effectiveness was brief and less harmful to the environment, and even to the development of more sophisticated systems for regulating pest populations. This is where research and application are now concentrating.

The popularity of Baker's "Eastern Forest Insects" soon made it unavailable. It is superseded by this volume, which closely follows Baker's format but provides additional information that is the result of another decade of research in entomology and forest pest management.

With the firm conviction that insect classification is the proper responsibility of specialists, keys to species are omitted. However, the user is helped to the degree possible by several keys to damage symptoms. The inevitable desire to apply standardized names to all things led to the biennial publication of approved common names of insects by the Entomological Society of America *(14, 1272)*. "Insects of Eastern Forests" follows the protocol of placing accepted common names before the scientific name and unapproved common names after the scientific names.

The rapidly changing situation for controlling insects mitigates against naming specific insecticides for this purpose. Current information can be obtained from agricultural extension specialists.

The biology, life history, and damage of eastern forest insects is emphasized in the text and illustrations to provide the reader with immediate background information required for intelligent decisionmaking. To further assist the reader in this

endeavor, an extensive list of literature citations is included[1] as are indexes to the scientific and common names of the insects and their tree and shrub hosts. Where possible, hosts follow the nomenclature of E. L. Little, Jr., "Checklist of United States Trees (Native and Naturalized)" (U.S. Department of Agriculture, Agriculture Handbook 541, 1979). A list of corresponding common and scientific names of plant hosts is also given.

[1] Italic numbers in parentheses refer to Literature Cited.

Forest Insects

Insects, the most abundant form of life on earth, also are numerically dominant in the forest. For over a period of some 350 million years they have evolved to occupy an incredibly wide variety of ecological niches. They serve many functions in the economy of the forest and are as essential a part of the complex associations as are the trees themselves *(674)*. Competition between people and insects for the forest and its products increased with the rise of human population. We demand much more of the shrinking forest environment now than we did in previous centuries. So, this competition is an ever-increasing problem that must be understood before it can be resolved.

By no means are all forest insects economically destructive. A multitude of species are beneficial. Along with other organisms they are important decomposers of forest debris—dead trees, fallen leaves, and such *(842, 843)*. Thus, they help return nutrients to the soil, increasing its fertility *(306)*. Others hasten the death of decadent, diseased, or overmature trees, making way for vigorous younger growing stock *(831)*. Many species of insects are parasites or predators of the destructive ones *(621)*. Some innocuous species are hosts for parasites of damaging insects, enabling the parasite population to remain at times when the population of destructive insects has declined or is in an unsusceptible stage.

Harmful forest insects and related forms are those that are responsible for economic loss. They include (1) species that damage or destroy the flowers and seeds of trees, and are particularly important pests in seed orchards and seed production areas; (2) species that stunt, deform, or kill nursery stock or young trees by damaging or destroying the buds, shoots, or roots; (3) species that cause loss of vitality, growth reduction, and often the death of trees by eating the foliage; (4) species that feed under the bark or in the wood of living trees and girdle and kill them or riddle them with tunnels; and (5) other destructive species that bore into and damage or destroy green logs, storm-felled timber, green-sawed and seasoned lumber, rustic construction, poles, posts, crossties, mine props, and all manner of finished products from flooring to furniture.

Most of our forest insects are native to the continent and are usually distributed throughout the ranges of their hosts. Some are destructive at normal population levels, but the majority commonly occur in such low numbers as to be of little or no consequence. A few of the latter, however, are capable of great and rapid increases in numbers when favorable environmental conditions prevail.

Eastern forests are also inhabited by many species of introduced insects, a few of which are widely distributed and extremely destructive. These include the gypsy moth, European pine shoot moth, balsam woolly adelgid, European pine sawfly, and the smaller European elm bark beetle. Many species of natural enemies of several introduced pests have also been imported and established in eastern forests.

Conditions conducive to forest insect outbreaks are only partly understood. It appears, though, that outbreaks are most likely to occur (1) in pure stands rather than in stands of mixed composition, (2) in overmature rather than in immature stands, and (3) in plantations rather than in natural stands. They may also develop

in stands weakened or decimated by hailstorms, flood, wind, drought, disease, fire, defoliation, or during logging operations. Outbreaks are likely to occur any time there is a breakdown in the effectiveness of natural control factors, or when changes occur in the genetic composition of populations, or in the age, composition, and density of stands.

Forest insect outbreaks vary greatly in frequency, size, and duration. Fortunately, the majority are small and short-lived, and usually consist of only one or a few "spots" in a stand or region. Unfortunately, some may expand until they encompass a few thousand square kilometers and last for many years before subsiding. From 1977 to 1981, more than 75 different species were recorded in outbreak status in eastern forests. Some 40 of these are considered to be of major importance *(581, 750)*. Many general discussions on forest insects are available *(21, 74, 76, 83, 314, 492, 605, 644, 674, 691, 767, 768, 1078, 1196)*.

Losses Caused by Forest Insects

Insects are among the most destructive agents affecting forest and shade trees. They are not only responsible for killing valuable trees and for the loss of growth or recoverable volumes from surviving damaged trees, but also they weaken or destroy wood structures. They are responsible for serious losses of other kinds, both tangible and intangible. Management plans are often upset and fire hazards increased, watersheds and wildlife habitats are impaired or destroyed, water in streams and lakes is polluted, the incidence and severity of floods are increased, and the attractiveness of parks and other recreational areas is reduced or destroyed. Heavy investments in tree improvement programs also are jeopardized or upset by the destruction of seeds and cones or valuable seed trees in seed orchards. Stand composition is often changed, leading to the displacement of valuable tree species by others of lesser value. Innumerable shade and ornamental trees around homes or along roadsides, and street trees of towns and cities, are killed or their attractiveness is greatly reduced or destroyed.

Forest Insect Surveys

It has long been recognized that successful control of forest insect outbreaks depends not only on the control method used but also on knowledge of the insect situation in immediate, surrounding areas. When an outbreak is discovered, it is necessary to know whether it is increasing or decreasing. It is also important to locate the center of greatest concentration and the direction of spread *(262)*. When an outbreak occurs, it is also important to know the value of the resources at stake and the status of natural control factors before decisions to apply control are made. Of like importance is the possession of a general knowledge of insect conditions throughout a timber type or region. This is helpful in developing plans for the detection of outbreaks in their early stages, a time when they may be suppressed most easily and economically and before heavy losses are incurred. Similarly, it is helpful to have a continuing record of the presence and abundance of the less spectacular types of insects to determine if, when, and where their number or damage is reaching economic levels of concern, even though not an outbreak. Where intensive management of the forest for timber or other objectives is being practiced, it is also important to have up-to-date information on all destructive pests to allow for their early control where needed. Such information is sought or acquired through surveys.

Forest insect surveys of various types have been made in the United States since the early days of this century *(137)* but, before the passage of the Forest Pest Control Act in 1947, they were usually conducted on a more or less unorganized basis. Passage of the act made it possible for the first time to conduct surveys on an organized, systematic basis on forest lands of all ownerships. In part, the act authorized the Secretary of Agriculture, either directly or in cooperation with other Departments of the Federal Government, with State and other public agencies, and with private organizations and individuals, to conduct surveys to detect and appraise insect infestations before they develop to outbreak proportions, to appraise their potential destructiveness, and to determine the needs for their control. Section 5 of the 1978 Cooperative Forestry Assistance Act (PL 95-313) retains these same provisions. Forest insect surveys are also conducted in Canada. There, the aim is not only to detect and appraise infestations but also to obtain information on the distribution, biology, and cycles of abundance of insect species for taxonomic and other purposes *(786)*.

Basically, forest insect surveys are of two kinds—detection and evaluation—and they may be conducted separately or together. Detection surveys are primarily for the purpose of discovering threatening infestations. Evaluation surveys are usually far more intensive and complex, being concerned with such factors as the intensity and the trends of pest populations, the identification and evaluation of natural control factors, the size and boundaries of infestations, the value of the resources at stake, and the possibilities of economic loss and an estimate of its magnitude if suppressive measures are not taken.

Many methods and techniques are employed in conducting surveys, the choice depending on many factors such as the insect species, its life history and habits, the nature of the damage it causes, the forest type and terrain, the size and accessibility of the area, a working knowledge of natural control factors affecting it, and the availability of trained personnel and funds. Aircraft are widely used in detection surveys and to a lesser extent in evaluation surveys. Conditions may be recorded by trained observers riding with the pilot *(6, 557, 559)* or by aerial photography *(4, 5, 108, 212, 296, 556, 558, 1256, 1257)*. Computers process the data, and radio-navigational aids keep the craft on the proper course *(346, 513)*. Panoramic aerial photography *(211)* and satellite imagery *(324)* are under study for delimiting outbreaks. The former is effective and cost competitive with earlier techniques, but the latter system is expensive and shows only heavy defoliation accurately. Unfortunately, evidence of infestation by many insect species is difficult or impossible to detect from the air. Where these insects are concerned, the only recourse is to use ground survey methods *(109, 1339)*. To the extent that it is possible to use them, aerial surveys are far less time consuming and costly than comparable ground surveys.

Ground surveys are not only required to detect infestations of many species but are essential for evaluation purposes. In most cases, they are complex and require the services of highly trained personnel. Ground surveys for evaluation purposes present many different sampling problems, such as when, where, and how to sample in order to obtain needed information within desired confidence limits. The choice of procedure is governed largely by the insect species and the intensity and size of the infestation. Pheromone traps are very useful to detect low populations of insects *(101, 1199)*. In addition to data on insect population density and size, data also may be collected to identify and record the abundance of natural control factors. In all cases information is sought and analyzed to determine two things:

what is likely to happen if no action is taken to suppress the infestation, and what might be expected to happen if suppressive measures are applied.

Sequential sampling techniques provide for flexibility in sample size in contrast to conventional techniques that usually specify a fixed number of sampling units to be examined. Units chosen at random from a sample are examined in sequence until the sample falls into one or more classes distinguished by specified limits *(1253)*. Sampling plans have been published for several important forest insect pests *(234, 235, 631, 632, 880, 1015, 1158)*.

Forest Insect Control

The impact of naturally occurring adverse environmental factors on forest insects is so great that the majority of species never occur in sufficient numbers to constitute an economic hazard. Even those insects that become sufficiently abundant at times to be considered "pests" are also subject to control by these factors, though usually to a lesser degree and frequency *(621, 630)*. Depending on the insect and the value of the forest resources affected, a given degree of natural control may reduce damage to an acceptable level.

Natural Control

Natural control results when naturally occurring adverse environmental factors prevent insect populations from reaching or exceeding harmful proportions. It may be effected by a single factor, such as abnormally low winter temperatures, or by several factors working in combination; it never ceases to function entirely, but its impact may fluctuate greatly from place to place and time to time *(21, 492, 621, 674)*.

Physical factors.—Temperature is one of the most important physical factors affecting forest insects. It not only sets limits to their distribution but also often profoundly affects their abundance. The optimum temperature for many eastern species appears to lie between 24° and 27° C; outside this range, insect activity gradually declines and eventually ceases. When temperatures climb to 50° C or drop to around −18° C or lower, death results. Rapid changes in temperatures, such as occur in the fall and spring, also may cause mortality even though absolute lethal temperatures are not reached.

Insects react in many ways to escape the rigors of adverse temperatures. During the summmer, leaf-feeding larvae may move from the upper to lower surfaces of leaves, or from the periphery of the crowns to the shaded interior to escape excessive heat. Solar-sensitive eggs may be deposited in the shade *(340)*. Adults find relief from heat by moving into the interior of stands, to the shaded portions of trunks, or to the interior of crowns. During cooler-than-normal days, they may seek out individual, exposed trees, the sunny side of trunks, or trees along the edges of stands. To escape the effects of winter cold, a species may hibernate in the egg, larval, pupal, or adult stage in areas where the likelihood of lethal temperatures occurring is greatly lessened. Because of physiological changes that occur in the dormant state, many northern species are able to survive temperatures well below −18° C. Southern species are much less likely to survive exposure to such temperatures.

Outbreaks of leaf-eating insects may be suppressed by late-spring frosts that kill the young, tender foliage which the young larvae depend on for food. Late springs may result in greatly delayed emergence from hibernation, and cool summers may result in a slowdown in the rate of larval development. Prolonged developmental periods add up to an extended period of exposure to parasites, predators, and disease pathogens, which may lead to unusually heavy losses. The number of generations produced per year may be related to photoperiod and the length of the season of biologically effective temperatures. In the South, a species may produce

five or more generations per year, whereas in the North, it may produce only one or less. Outbreaks of such a species often appear to develop with explosive suddenness in the South. In the North, it may require several years for an equivalent outbreak to occur.

Insect populations are also affected by atmospheric moisture and by moisture conditions in host trees and in the soil. For example, various species of wood borers, such as powderpost beetles, breed successfully only in very dry wood, whereas others, such as the ambrosia beetles, require wood with a much higher moisture content. Damage to black locust by the locust borer and to pines by various species of bark beetles may be greatly intensified during or following periods of drought.

A considerable degree of control also may be effected by other adverse weather conditions. For example, heavy, beating rains may dislodge and destroy large numbers of larvae that feed on the foliage of trees; moist weather may result in the development of disease epizootics and the decimation of insect populations.

Host factors.—Many species of forest insects feed on only a few species of trees. Some of the most serious bark beetle pests belong to this group. Many species of destructive wood borers also confine their attacks to several closely related species. In contrast, numerous other species feed on a great many tree species, often in different families. Many leaf-eating species belong to this group. The females of some insects deposit their eggs in all kinds of places; others deposit them on host trees only. When the former condition prevails, it often leads to heavy losses among newly hatched larvae, especially where acceptable food is not readily available. Infestations of species that develop in weak or decadent trees may disappear or be greatly reduced when the ratio of these trees to healthy vigorous trees drops below a critical level in a stand.

Populations of multiple-host species, many of which attack trees in all stages of health or vigor, may be held to low levels in mixed stands that contain a low ratio of preferred to nonpreferred host species.

Biotic factors.—Parasites, predators, and pathogenic micro-organisms play important roles in the natural control of insects. Their effects may not always be evident, but they always bring some degree of pressure to bear on their hosts, and it is often severe. Occasionally, when a virus epizootic develops, the results may be catastrophic for the host insects. Operating singly or in combination, biotic factors may limit the duration and magnitude of an outbreak, prolong the intervals between outbreaks, or prevent outbreaks entirely. A large number of these control agents have been collected and identified in the forests of eastern America, and new ones are being added to the list each year.

Insect control by biotic factors has several advantages not offered by many of the other approaches to control now available. Where these factors are well established, they usually are self-perpetuating, barring natural catastrophies or interference by humans; they adjust to changes in the size of host populations, and they operate with practically no adverse side effects.

The majority of the parasites and predators of insects are other insects. Many thousands of species belonging to well over 200 families in 15 orders are known to be either parasitic or predacious; many of these attack forest insects. The majority of parasitic forms belong to only a few families in the orders Hymenoptera and Diptera. Important predators are found in several families of the orders Coleoptera, Diptera, Neuroptera, Hemiptera, and Hymenoptera.

Parasitic and predacious insects differ widely in habits and behavior. A parasite usually requires only one host in which to complete its development; a predator usually requires several to many hosts for its development. A parasite usually does not kill its host until it has completed its own development; a predator usually kills its host as soon as it is encountered. Host selection by parasites is generally a function of the egg-laying female adult only; whereas each individual predator must search out hosts in all of the feeding stages.

Forest insects are also fed upon by many other forms of animal life, principally spiders, mites, birds, and many mammals. Birds, especially woodpeckers, are sometimes effective in suppressing outbreaks. Many other species of birds are also thought to play important roles in control *(190, 470, 864)*. Small mammals such as shrews are often effective in controlling species that spend part of their lives on the ground *(170)*.

The literature contains many references to the role of parasites and predators in insect control. A good introduction to the subject is in several publications *(26, 48, 170, 216, 218, 240, 284, 621, 1183, 1203, 1213)*.

Many species of forest insects are also subject to a considerable degree of control by pathogenic micro-organisms. Some of the latter, especially the viruses in the family Baculoviridae, frequently occur in the form of epizootics and decimate or eliminate outbreaks over large areas. The baculo viruses are particularly useful because they infect only invertebrates. Notable examples are (1) a polyhedrosis virus disease that ultimately plays a leading role in the control of gypsy moth outbreaks in the Northeast, and (2) a disease of the same type that caused the collapse of an outbreak of the European spruce sawfly over a region of several thousand square kilometers in eastern Canada and the Northeastern States during the late 1930's.

There are more than 1,300 different kinds of micro-organisms, most of which are pathogenic, that have been found associated with insects. This includes 22 types of viral diseases in 826 hosts, and a total of 1,271 host-virus records *(815)*, 100 species of bacteria *(907)*, 750 species of fungi *(907)*, 300 species of protozoa *(907)*, several rickettsiellas, and about 1,000 species of nematodes *(991)*. Generally speaking, they gain entry into the insect by being ingested with food, during hatching from contaminated eggs, through wounds or other damaged areas in the integument, or through the tracheae. Most of them rely on wind, rain, streams, healthy or contaminated insects, small mammals, or birds for dispersal throughout an insect infestation or outbreak. Spread is occasionally so rapid that all of the insects in an infestation may appear to be dying at the same time.

Many species of forest insects are particularly susceptible to viruses of the nuclear-polyhedrosis type *(873)*. Once inside the host these viruses enter the cell nuclei, replicate, and some virions become encapsulated in many-sided, rodlike crystals, known as polyhedra. Invaded cells are soon destroyed, the virions and polyhedra are then released in the body cavity, and the host dies. Diseased larvae usually become sluggish, cease feeding, and in some instances move upward in the trees. After death they may be seen hanging by their forelegs, with the body darkened, decomposed, and liquified. Eventually they completely disintegrate and dry up on the trees.

Forest insects are also affected by several other kinds of viruses—cytoplasmic polyhedrosis, granulosis, polymorphic inclusion, and noninclusion. Generally speaking, these viruses appear to be less effective and less specific in control than

those of the nuclear-polyhedrosis type. Further information on viruses is available *(96, 113, 622, 816, 1145, 1153)*.

Several species of bacteria produce so-called milky diseases in the insect host, the best known being the milky disease of Japanese beetle larvae *(350)*. The larvae of many closely related species of beetles are also affected by this disease. Scores of species of Lepidoptera and apparently several species of Hymenoptera, Coleoptera, Diptera, and Orthoptera are susceptible to diseases caused by various crystalliferous bacteria, the best known of which are several varieties of *Bacillus thuringiensis* Berliner *(343, 344, 347, 549, 550, 709)*.

Some species of fungi occasionally cause significant reductions in insect populations. Aphids are particularly susceptible to attack by species of *Entomophthora*. The species *E. megasperma* Cohn was credited with causing a high degree of control of the forest tent caterpillar in Ontario. Another species, *Beauveria bassiana* (Balsamo) Vuillemin, reportedly killed more than 90 percent of the larvae of the smaller European elm bark beetle in a number of infested elm trees in Connecticut *(311)*. Pathogenic fungi, such as *Paecilomyces* sp., *Beauvaria bassiana, Metarhizium anisopliae*, etc., killed nearly one-third of the southern pine beetles in the field *(867)*. Laboratory testing has confirmed the activity of these fungi against the southern pine beetle *(954)*.

Many species of pathogenic Protozoa are also associated with forest insects *(652, 1094, 1125)*. Generally speaking, these pathogens prolong the length of the larval stage and reduce the fecundity of surviving adults.

Numerous species of nemotodes may be found in the gut, the hemocoel, or in particular organs such as the Malpighian tubules of insects. Some of these kill the host when they emerge, some cause death by initiating the action of lethal microbial disease agents *(1265)*. Some cause injury but not death *(91)*. Certain species infesting bark beetles riddle the intestines and gonads of their hosts, block the ducts, and cause the ovaries to shrivel. This may lead to a marked reduction in egg production by infested female beetles and a sharp decline in beetle populations *(826)*. The literature on the subject has been reviewed *(1270)*.

Applied Control

When natural control factors fail to hold populations to economically tolerable levels, it may be necessary to apply silvicultural, chemical, or other controls to enhance, supplement, or serve as substitutes for natural control. Depending on the insect and its biology and ecological relationships, a wide variety of materials and methods are available for suppressing populations. These may be applied directly against the insect to interfere with its growth or reproduction, or to kill it; or they may be applied to the environment to render it less favorable for the insect through alteration in food supply, in microclimatic factors, or in the abundance and effectiveness of natural enemies.

The choice of materials or methods in artificial control depends on several things: whether the insect is a native or introduced species, the factors known or thought to be responsible for its abundance, the need for quick and effective reduction in its numbers, and cost. If a native species is involved, usually the aim is not to eradicate it, but rather to reduce its numbers to a tolerable level; if it is a recently introduced pest, the aim may be to eradicate it or to slow down or prevent its spread.

Artificial controls designed to suppress existing outbreaks usually have short-term effects only; those that are used for the prevention of outbreaks may be long

lasting. They may also cause increases in nontarget pest populations *(755, 912)*. Control costs vary considerably, depending on the insect and its habits, the methods and materials used, and the size and accessibility of infested stands. It may cost only several dollars per hectare for infested stands treated with aerial application of insecticides or it may cost several dollars per tree for individual treatments. Regardless of the control method employed, the benefits from its use should usually outweigh costs. Different methods of control involve different hazards; care must be taken in the use of any of these control methods. Occasionally, control costs may be retrieved through the salvage and sale of infested timber.

Silvicultural Control

Insect population density is influenced by the composition and condition of forest stands. Because of this, it is sometimes possible to create unfavorable conditions through the application of carefully designed cultural or management practices. Efforts directed toward this end are commonly called silvicultural control.

Possibilities of silvicultural control occur during the establishment and throughout the lives of stands by properly timed planting, by selecting the more resistant tree species for planting, by putting them on sites best suited for them, or by controlling their composition and density. Stand conditions may be created or modified as needed by thinnings or cuttings. Pure stands may be broken up into mixtures of age classes in small units, with no two contiguous units of the same age class. Mixed stands may be broken up by cutting in small groups to maintain and promote diversification in species composition and density. Overmature trees may be removed from stands and the stands harvested as soon as they mature. High-risk trees may be removed in sanitation-salvage cuttings *(659, 1051)*. Further discussions of silvicultural control are available *(85, 457, 674, 1000, 1139, 1198)*.

Physical and Mechanical Methods of Control

Many forest, shade tree, and wood products insect pests are amenable to control by physical or mechanical methods. The method chosen is dictated by such factors as the habits and behavior of the insect pest involved, the location and value of the trees or products attacked, and cost.

Trap trees and trap logs are sometimes effective in the control of bark beetles *(903)*. Bands of tanglefoot or similar materials may be placed around the trunks of shade trees to prevent larvae or wingless female adults of several species, such as the fall cankerworm, from ascending the trees to feed or oviposit. Young, newly planted shade trees may be protected from borers of various kinds by enclosing the trunks in wrapping paper. Bagworms on ornamental trees may be controlled by handpicking. Subterranean termites can be kept out of structures by capping foundations with a 10-cm layer of high-grade concrete or with properly applied metal shields, by keeping untreated wood from contact with the ground, by using solid foundation masonry, and by providing good ventilation between the ground and timbers *(12)*. Similar treatments prevent damage by the old house borer *(870)*.

Logging and milling infested timber and destroying the slabs that contain the broods are often effective in preventing bark beetle outbreaks. Such methods may be feasible only where the trees are of merchantable size, are accessible, and when they can be harvested promptly. Bark beetle broods in or under the bark may also be killed by storing infested logs in water, by peeling infested logs and burning the

bark, by sawing infested trees into short lengths and burning them, and by peeling the bark of infested trees and exposing the brood to desiccation and to natural enemies such as ants, birds, and small mammals. Felling infested trees in a north-south direction in the open and periodically rotating them kills the beetles by solar heat.

Ambrosia beetle damage to summer-cut logs can be reduced or prevented by quickly removing the logs from the woods, by quickly manufacturing them or storing them in ponds, by quickly drying the lumber cut from them, and by removing the bark from rough-hewn pieces.

Ips bark beetle populations that sometimes develop in slash following cutting operations can be reduced by limiting small-scale cuttings to the fall and winter months, or by continuing large-scale cuttings throughout the summer months. In situations where it is necessary to cut on a small scale or discontinuously during the summer, control may be obtained by piling and burning the slash before the beetles complete their development in it. Gathering and burning severed branches late in the fall, winter, or early spring when the eggs and grubs are in the twigs is an effective method of controlling twig-girdling species.

Wood-borer damage to field-piled pulpwood in the Lake States has been reduced by piling the wood in the shade or by placing it in standard compact piles. *Lyctus* powderpost beetle damage can be reduced by storing susceptible sapwood in water for a lengthy period or by steaming it at high temperatures. Bark beetle damage to bark-covered poles and slabs used in rustic construction can be reduced or prevented by cutting the material during the fall and winter and then seasoning it off the ground and under cover. Damage to young pines by the European pine shoot moth in the North can be reduced by removing the lower limbs, so that the overwintering stage of the shoot moth will occur on branches above the snow line where they will be killed by lethal low temperatures during the winter *(1337)*.

Regulatory Control

Regulatory control is aimed at the prevention of entry and establishment of foreign plant and animal pests, or at the suppression, containment, or eradication of such pests as may have become established in limited areas. This form of control became possible with the passage of the Federal Insect Pest Act in 1905, which enabled the Federal Government to regulate the importation and interstate movement of articles that might spread insect pests. It was reinforced in 1912 by passage of the Plant Quarantine Act, which authorized the Secretary of Agriculture to enforce necessary regulations to protect the agricultural ecomomy of the United States by preventing the introduction of insects and plant diseases. Later the McNary-McSweeney Act of 1928 established a Federal policy on the use of legislative means for combating forest insects and diseases. In 1947, passage of the Forest Pest Control Act provided authority for the United States Government to act alone or in cooperation with States, territories, or private timber owners to control destructive forest insects or diseases.

Before the passage and enforcement of quarantine laws, many species of insects associated with forest, shade, and ornamental trees, several of which are highly destructive, gained entry into the Eastern United States. Since then the rate of entry of additional species has been drastically reduced. The following is a list of species known to have been introduced into this area:

Order and Species	Origin	Principal food plant
Orthoptera		
Gryllotalpa gryllotalpa (L.)	Europe	Nursery stock
Hemiptera		
Stephanitis rhododendri Horvath	Europe	Rhododendron
Isoptera		
Coptotermes formosanus Shiraki	Far East	Wood products
Homoptera		
Adelges abietis L.	Europe	Spruce
A. piceae (Ratzeburg)	Europe	True firs
A. laricis Vallot	Europe	Spruce
Asterolecanium variolosum (Ratzeburg)	Europe	Oak
Cryptococcus fagisuga Lindinger	Europe	Beech
Gossyparia spuria (Modeer)	Europe	Elm
Matsucoccus resinosae Bean & Godwin	?	Red pine
Pealius azaleae (Bean & Moles)	Asia	Azalea
Phenacoccus acericola King	Europe	Sugar maple
Pineus strobi (Hartig)	Europe	Pine
Pseudococcus comstocki (Kuwana)	Far East	Deciduous trees
Quadraspidiotus perniciosus (Comstock)	China	Deciduous trees
Coleoptera		
Anobium punctatum (De Geer)	Europe	Wood products
Anomala orientalis Waterhouse	Philippines	Nursery stock
Brachyderes incanus (L.)	Europe	Pine
Callirhopalus bifasciatus (Roelofs)	Japan	Ornamentals
Chlorophorus annularis (F.)	Japan, India	Stored bamboo
Chrysomela interrupta F.	Europe	Willow, poplar
C. crotchi Brown	Europe	Willow, poplar
Cryptorhynchus lapathi (L.)	Europe	Poplar
Cyrtepistomus castaneus (Roelofs)	Japan	Oak
Heterobostrychus aequalis (Waterhouse)	Far East	Oak & mahogany boards
Hylotrupes bajulus (L.)	Europe	Seasoned coniferous wood
Maladera castanea (Arrow)	Orient	Deciduous trees
Minthea rugicollis (Walker)	Antilles(?)	Oak flooring
Nacerdes melanura (L.)	Europe	Wooden wharves, piling
Otiorhynchus ovatus (L.)	Europe	Conifers
O. sulcatus (F.)	Europe	Confers, broadleaf plants

Phyllobius oblongus (L.)	Europe	Deciduous trees
P. intrusus Kono	Japan	Thuja, juniper
Plagiodera versicolora (Laicharteg)	Europe, Japan	Willow
Polydrusus impressifrons (Gyllenhall)	Europe	Poplar
Popillia japonica Newman	Japan	Wide variety of plants
Pyrrhalta luteola (Müller)	Europe	Elm
Rhizotrogus (= *Amphimallon*) *majalis*	Europe	Various plants
Sciaphillus asperatus Bonsdorf	Europe	Maples, birch, hazel, hophorn-bean
Scolytus multistriatus (Marsham)	Europe	Elm
Xestobium rufovillosum De Geer	Europe	Wood products
Zengophora scutellaris Suffrian	Europe	Poplar
Lepidoptera		
Aethes rutilana (Hübner)	Europe	Juniper
Anthophila pariana (Clerck)	Europe	Apple, thorn
Archips rosanus (L.)	Europe	Deciduous trees, privet
Chrysoclista linneella Clerck	Europe	Linden
Cnidocampa flavescens (Walker)	Asia	Norway maple
Coleophora laricella (Hübner)	Europe, Japan	Larch
C. ulmifoliella McDunnough	Europe	Elm
C. serratella (L.)	?	Birch
Dichomeris marginella (Denis & Schiffermüller)	Europe	Juniper
Epinotia nanana (Treitschke)	Europe	Spruce
Etainia sericopeza (Zeller)	Europe	Norway maple
Euproctis chrysorrhoea (L.)	Europe	Apple, pear
Gracillaria syringella (F.)	Europe	Lilac
Homadaula anisocentra Meyrick	?	Mimosa, honeylocust
Leucoma salicis (L.)	Europe	Poplar, willow
Lymantria dispar (L.)	Europe	Oak, etc.
Orgyia antiqua (L.)	Europe	Deciduous trees
Rhyacionia buoliana (Denis & Schiffermüller)	Europe	Pines
Samia cynthia (Drury)	Asia	Ailanthus, cherry
Sesia apiformis (Clerck)	Europe	Poplar
Spilonota ocellana (Denis & Schiffermüller)		
Zeuzera pyrina (L.)	Europe	Elm, maple
Diptera		
Monarthropalpus buxi (Laboulbène)	Europe	Boxwood
Rhabdophaga salicis (Schrank)	Europe	Willow

Hymenoptera

Acantholyda erythrocephala (L.)	Europe, Japan	Pine
Caliroa cerasi (L.)	Europe	Cherry, shadbush
Diprion similis (Hartig)	Europe	Pine
Eriotremex formosanus (Matsumura)	Asia, Taiwan	Oak
Fenusa dohrnii (Tischbein)	Europe	Alder
F. pusilla (Lepeletier)	Europe	Birch
F. ulmi Sundevall	Europe	Elm
Gilpinia frutetorum (F.)	Europe	Pine
G. hercyniae (Hartig)	Europe	Spruce
Hemichroa crocea (Geoffroy)	Europe	Alder
Heterarthrus nemoratus (Fallén)	Europe	Birch
Neodiprion sertifer (Geoffroy)	Europe	Pine
Pristiphora erichsonii (Hartig)	Eurasia	Larch
P. geniculata (Hartig)	Europe	Mountain-ash
Profenusa thomsoni (Konow)	Eurasia	Birch
Sirex juvencus juvencus (L.)	Europe	Pine, fir, spruce
Solenopsis invicta (Buren)	South America	General feeder
Trichiocampus viminalis (Fallén)	Europe	Poplar

Biological Control

Biological control, in the classical sense, implies the introduction of alien parasites, predators, or disease organisms to suppress pest populations below an economically damaging level. The forest environment is the most stable plant community; therefore, it should be admirably suited to the practice of biological control. In fact, a number of introduced forest insects have been subjected to this type of control with great success, and some others with less success. The exposed feeders—defoliators and sucking insects—are most readily suppressed; insects that feed cryptically—such as bark beetles and borers—are least likely to succumb to biological control.

Success in this field of endeavor is favored by proper packaging, rapid transportation, good communication between shipper and receiver, and also among customs, quarantine, and postal officials. Contrarily, poor communication between parties, inefficient customs, quarantines, and postal services, may ruin biological control attempts. Political strife between nations may also interfere with the conduct of biological control operations.

Generally speaking, biological control efforts against forest insects have been limited to (1) the importation and establishment of foreign parasites and predators of introduced pests; (2) the transfer of parasites, predators, and disease pathogens from one region to another within the country; (3) the augmentation of established parasite and predator populations with field-collected or laboratory-reared individuals; and (4) the use of microbial sprays to control outbreaks.

The majority of importations of parasites and predators made before World War II emphasized enemies of the gypsy moth, browntail moth, satin moth *(173, 174, 613)*, European pine shoot moth, European pine sawfly, European spruce sawfly, balsam woolly adelgid, and larch casebearer. Since then, importations have been limited mostly to enemies of the gypsy moth, balsam woolly adelgid, larch

casebearer, and the smaller European elm bark beetle. By 1982 a total of 264 species of parasites and predators had been imported and liberated against 60 species of introduced and native pests. Of these, a total of 50 are known to be established. Beginning in the early 1930's, the Canadian government also imported large numbers of many species of parasites and predators against a number of pests, many of which also occur in the United States *(227, 788)*. Some of these biological control agents have spread into adjoining areas of the United States. Large numbers of others have been shipped to this country and liberated in infested stands.

A polyhedrosis virus disease of the gypsy moth accidentally introduced into the United States in the early 1900's has since played an important role in the control of outbreaks of its host. Like others of its kind, this virus is most effective in dense populations and is almost unnoticeable in light infestations. A microbial spray formulation of this virus has been developed and registered under the name Gypchek *(732)*.

Applications of polyhedrosis virus sprays have been used to suppress populations of the European pine sawfly *(112)*, the Virginia pine sawfly *(790)*, the Swaine jack pine sawfly *(1095)*, and the redheaded pine sawfly *(292, 1145)*. Virus epizootics have been initiated in populations of the forest tent caterpillar by disseminating the virus during one generation *(1144)*. Other important eastern forest insects that are subject to polyhedrosis virus diseases are European spruce sawfly, eastern tent caterpillar, fall webworm, linden looper, whitemarked tussock moth, winter moth, jack pine sawfly, and the blackheaded pine sawfly.

Viruses are usually applied as sprays, but they may also be applied as dusts if first incorporated with powder. Sprays may be applied by hand-operated sprayers, mist blowers, or aircraft. Experimental vectoring with contaminated parasites or males may simplify distribution of viruses in the future.

Considerable progress has been made in the control of a number of lepidopterous defoliators with *Bacillus thuringiensis*. The HD-1 isolate of *B. thuringiensis* is now used commercially against many forest insect defoliators, including gypsy moth, spruce budworm, Douglas-fir tussock moth, tent caterpillars, webworms, and cankerworms.

Chemical Control

The use of chemicals to suppress forest insect populations is usually a method of last resort. It should be the practice to use them only when other forms of control, either natural or artificial, fail or threaten to fail in the prevention or control of destructive populations. Chemical insecticides sometimes may complicate the resolution of an insect problem *(642,755)*. Depending on the situation, chemicals may be applied to a single tree or to forested areas covering thousands of hectares or square kilometers. The aim, therefore, is usually limited to the suppression of injurious populations to tolerable levels.

Many different types of equipment and techniques are available for applying insecticides *(993)*. Aerial applications are made to large areas by fixed-wing aircraft (fig. 1) or helicopters *(51, 59, 90, 354, 627, 641)*. Individual trees, small groups of trees, and seed orchard trees (fig. 2) may be treated by ground equipment such as mist blowers *(290, 994)* or by knapsack sprayers. Large individual trees may be treated by mist blowers and by hydraulic sprayers *(838)*. Logs are treated by knapsack and power sprayers *(1040)*. Fogging machines are sometimes used around

resorts and campgrounds. Systemic insecticides may be applied by trunk implantation or injection *(837, 838)*, by banding or spraying the circumference of the trunk, by spraying the foliage, by treating the soil around the base of trees *(55, 1364)*, or by dipping seedlings or cuttings before planting *(57, 320, 703, 837, 874, 940, 1311)*.

F-482299

Figure 1.—Airplane-spraying for spruce budworm control.

F-517833

Figure 2.—Mist-blower application of insecticide to pine trees in a seed orchard.

The effectiveness of chemicals in suppressing many forest insect populations has been amply demonstrated. A large number of new insecticides and methods of application have come into extensive use, and outbreaks covering thousands of square kilometers of forest have been suppressed. As effective as insecticidal control has been, however, it has not proved to be an unmixed blessing. Chemical insecticides have been associated with known or suspected adverse side effects caused by some of the more commonly used chemicals. This stems from the fact that these chemicals are nonspecific and may be harmful to at least some other exposed animal species *(254)*. The problem is compounded in that some chemical insecticides are very persistent *(953, 1358)*, that all of the material applied in a given environment may not remain there, and that free-ranging animals cannot be excluded from sprayed areas *(560)*. The deleterious effects of these insecticides on food chains are known by the failure of carnivorous birds to reproduce *(585)* and by the appearance of fish unfit for human consumption. Public awareness of known and possible hazards associated with the use of these chemicals has given rise to concern over their continued widespread use.

Efforts are unceasing to discover and develop new and safer insecticides *(1005)*. Insecticidal accumulations in the tissues of wildlife need to be determined as a basis for indicating when undesirable damage to the biota might occur. Application techniques and equipment are being refined to provide better control of the placement of insecticides in the environment and to further lessen the dangers of undesirable side effects. Studies are being made to improve sampling and biological evaluation techniques as a basis for improving the timing of application and to ensure that insecticides are applied in the proper amount, and only when and where they are needed. Joint genetic and toxicological studies should lead toward efficient application and minimal environmental contamination *(1166, 1167)*.

The rapid changes occurring in the development and use of insecticides in forest insect control make it inadvisable to include control recommendations in this publication. Furthermore, no insecticides should be used to control an insect unless recommendations are registered by the Environmental Protection Agency *(1225)*. When using any pesticide, remember to: (1) read the entire label before opening the container, (2) meticulously follow application and disposal directions, and (3) be certain to consult your County Agent or another specialist regarding any use not explicitly mentioned on the label *(1225, 1242, 1273)*.

Other Approaches to Control

Many conventional methods of suppressing forest insect populations are effective, but they are all found wanting in important respects. Insecticides are often entirely effective, but they usually cannot be applied to large areas without endangering other forms of animal life. Furthermore, they usually do not hold pest populations to subeconomic levels for long, nor do they reduce the vulnerability of stands to future outbreaks. Most forms of biological control cannot be depended upon to suppress an outbreak before damage has occurred. They may also be incapable of preventing outbreaks, although they may reduce their frequency of occurrence and their magnitude, intensity, and duration. Because of these deficiencies, as well as those of other current methods of control, intensive research is underway to develop new or improved methods and materials which may be used as complements, supplements, or substitutes for them.

Sexual sterilization is receiving much current attention because of its potential use as a new method of control. The effectiveness of releasing males sterilized by gamma radiation was established in the mid-1950's when they were used to eradicate the screwworm, *Cochliomyia hominivorax* (Coquerel), from Curacao, West Indies, and from the southeastern portions of its range in the United States. The principles of sexual sterilization of insects are discussed in several papers *(676, 677, 678, 679, 680)*. Several authors reported the research that led to the method and its use against the screwworm *(179, 180, 181, 734, 735)*. Research on the sterilization of some important forest insects has not been promising *(51, 637)*. However, in new work on the gypsy moth, use of the sterile-male technique with wholly or partially sterile males, shows good promise for eliminating isolated populations. Partially sterile males produce sterilized F_1 generations *(1073)*. Further research must be conducted before the full possibilities of using the sterile-male release technique for forest insect control can be determined.

Chemically induced sterility also offers promise as a control measure. The appropriate chemicals are called chemosterilants because of their capacity to deprive insects of the ability to reproduce *(139, 1018)*. Most of the chemosterilants that offer promise for practical control are mutagenic and can be used only in ways that will avoid all contact between them and nontarget animals *(907)*. Chemosterilants may be added to the insects' food or applied to surfaces to which the insects are attracted. Those mixed with food appear to produce maximum effectiveness and minimum hazard. So far, none is available for use in forest insect control.

Insect repellents can be useful alternatives to the use of chemical insecticides. Considerable research, development, and use of repellents is associated with insects and related animals of importance to public health. However, relatively little emphasis has been placed on insects that damage trees or their products.

Tests of organotins indicate that they deter feeding by the pales weevil *(1197)*. Certain products of the neem tree also show deterrent capability *(182, 708)*. Pine oil, a by-product of sulfate pulping, shows promise as a repellent of several *Dendroctonus* spp. *(931)*.

Insect attractants are being given increased research attention to improve or reduce the cost of surveys and to open up new opportunities in integrated pest management of forest insects *(99, 186)*. Some of these materials are powerful enough to lure insects over considerable distances. Attractants of many kinds are being studied, but those consisting of natural chemicals produced by host plants or the insects themselves are receiving the most attention.

Many important forest insects in the orders Lepidoptera, Coleoptera, and Hymenoptera produce sex attractants. They may be emitted directly from the insect, or they may emanate from the frass or excrement left from insects feeding under the bark *(1082)*. The material emitted by certain species is enormously attractive. One female of the introduced pine sawfly attracted more than 11,000 males *(239)*.

Sex attractants have long been used to some extent in surveys of a few forest insects, particularly the gypsy moth *(225)*. For many years the tips of abdomens of virgin female moths were placed in specially designed traps to capture male moths. Research to improve on this technique led to the isolation and synthesis of the attractant material *(634)*, and the subsequent synthesis of a closely related, comparatively inexpensive, highly attractive material called disparlure *(106)*. Synthetic attractants are now used widely for detecting and evaluating gypsy moth as well as other forest insects, such as Douglas-fir tussock moth, Nantucket pine tip moth,

European pine shoot moth, introduced pine sawfly, western pine shoot borer *(Eucosma sonomana* Kearfott), and spruce budworms.

Beginning with the isolation, identification, and synthesis of the pheromone of the western pine beetle *(Dendroctonus brevicomis* LeConte) *(1082)*, aggregating or sex pheromones of a number of bark beetles important to forestry have been isolated and identified. These include compounds from four species of *Ips* and five species of *Dendroctonus*. In most instances, a complex of two or more substances has been shown to exist. Individual chemicals in a particular species complex may be produced by either males or females and have highly specific behavioral functions. Among these functions are sex attraction, aggregation, antiaggregation, attack termination, and species isolation. In the case of both the western pine beetle and the elm bark beetle, the synthesized form of attractant/aggregant has been evaluated in large-scale field studies. A broader coverage of progress and developments is available *(110, 633)*.

Several other approaches to control are also being investigated. These include the selection and breeding of hybrids and varieties of trees resistant to attack by a number of important insects *(472, 849, 1114)*, as well as the discovery or breeding of more vigorous strains of natural enemies, the introduction of detrimental genetic traits into pest insects, and the identification and isolation of chemicals responsible for host resistance or attraction *(1116, 1117, 1118)*. To a great extent, knowledge of the enzymatic composition of pest and parasite insects is basic to understanding success with alternatives to chemical control. The value of such studies will be recognized increasingly *(200)*. Studies are also being conducted on the use of insect growth regulators that interrupt larval development by preventing the normal molting process. Laboratory and field tests show that these materials have great promise *(1019, 1020, 1031, 1286)*.

Integrated Pest Management

The publication of "Silent Spring" *(199)* in 1962 focused the attention not only of Americans but also of people around the world on the serious question of the continued use of broad-spectrum pesticides that persist in the environment. Within a few years the use of many pesticides of this type was either banned or severely restricted worldwide. As a result of all this, an urgent need for alternative materials and methods was made sharply evident. Although many associated problems are yet to be solved, modern instrumentation, analytical chemistry, and essentially artificial diets for insects, have strongly supported the advances that are in progress. The twin goals of sophisticated systems to suppress populations of threatening pests are now based upon the application of a range of techniques designed to maximize pest management within economic tolerance and minimize or eliminate environmental trauma. The term "Integrated Pest Management" is designed to identify these systems. Therefore, for the purpose of definition, integrated pest management (IPM), is a system that utilizes all suitable techniques and methods of pest prevention and suppression, in the context of good ecological practice, to maintain pest population levels below those causing economic injury *(313, 1195)*.

Most of the important pest species in eastern forests lend themselves to some form and degree of IPM. The long life of the forest crop, and the fact that many species of commercially valuable trees can withstand some degree of infestation without serious damage, provide the opportunity to use different methods of management in the majority of cases.

Since early in this century, considerable emphasis has been placed on importing and augmenting natural enemies of many species of introduced pests *(218, 613)*. In many cases, the dispersal of these imported enemies has been accelerated by the transfer of colonies to distant infested areas *(299, 341, 704)*. The increase in numbers after successful establishment of several species has also been helped by the use of large numbers of field-collected or laboratory-reared individuals *(647, 928)*.

The presence and abundance of natural enemies is taken into consideration in deciding whether to suppress an outbreak and in planning how to accomplish it. For example, the sudden appearance of a virus disease among the damaging insects in heavily infested stands usually portends the imminent collapse of the outbreak. Therefore, when evidence of this disease is encountered during surveys, it is often decided to withhold other methods of control, particularly the application of insecticide. Observation of abnormally high percentages of natural control provided by insect parasites and predators leads to a similar decision. In other situations where insecticidal control is deemed necessary, it is often possible to limit application to designated portions of infested areas because of the abundance of natural enemies in other portions *(673)*.

Knowledge of the population dynamics of a pest species provides opportunities for various other means of preventing or reducing losses, thereby eliminating the need for direct, suppressive measures to control outbreaks. The genetic basis for insect behavior is being explored to suggest and explain responses to pest management practices *(428)*. Depending on the situation, outbreaks of certain leaf-feeding insects may be prevented or minimized by modifying the composition and density of susceptible stands *(313, 751)*. It is often possible to prevent or suppress outbreaks of some bark beetles by thinning the stand, removing infested slash, or salvaging infested trees before the emergence of beetle broods from the bark *(1195)*. The utilization of mature trees growing on poor sites before the trees begin to deteriorate and become attractive to borers, such as the hemlock or bronze birch borers, is a recommended control practice. The avoidance of unfavorable sites in planting programs is recommended for preventing damage by certain species *(515, 548)*. Adherence to good construction methods when building structures reduces the need for chemical control of termites later *(1050)*. The destruction of elm material suitable for breeding by the smaller European elm bark beetle reduces the need for the use of insecticides in Dutch elm disease control *(1287)*.

Some of the new approaches to biological control, many of which are yet to be perfected, may be expected to provide additional opportunities for IPM in the coming years. These include the combined use of insect growth regulators or microbial insecticides with pheromone traps to rid the sprayed zone of remaining male insects. Application of these new-generation insecticides can be followed by the liberation of massive numbers of parasites, some species of which are known not to overwinter in the region. Comprehensive treatments of insect-pest management have been published *(313, 664, 907, 1008, 1195)*.

Insects are involved directly or indirectly in the transmission of many serious diseases of forest and shade trees in the Eastern United States. Some of these diseases, such as Dutch elm disease and elm phloem necrosis, are among the most devastating tree diseases known. The majority of tree diseases are caused by various species of fungi. However, phanerogams, bacteria viruses, mycoplasmas, and rickettsiae also cause plant diseases. Some disease organisms, such as those causing Dutch elm disease and chestnut blight, attack living, healthy trees and kill them quickly. Other diseases, such as stains and heartrots, occur in living trees weakened or injured by environmental conditions.

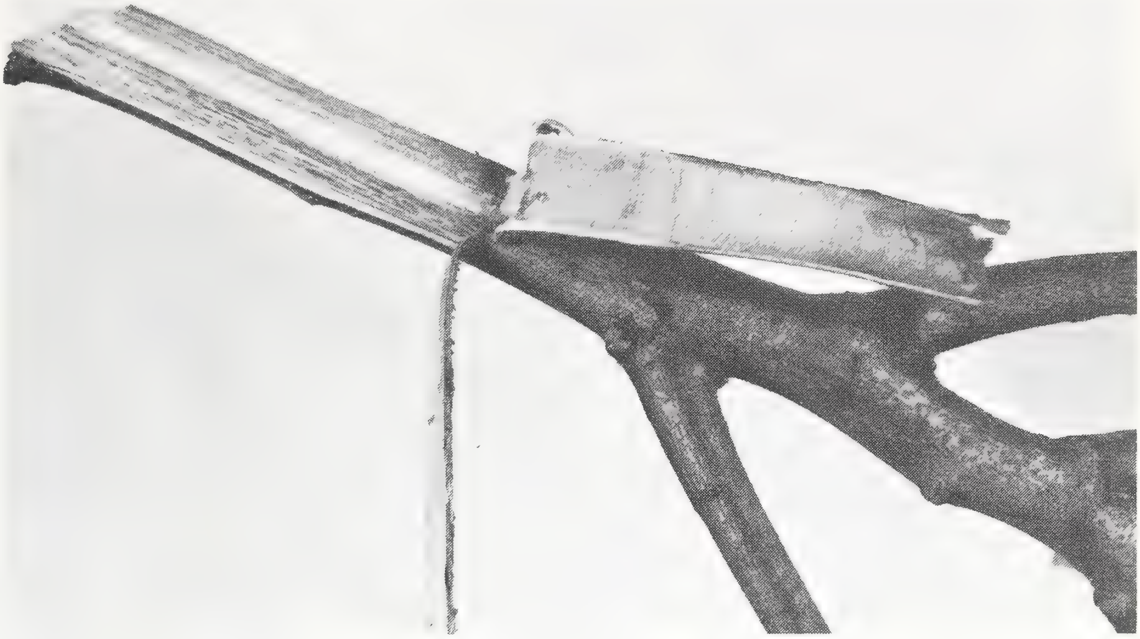
Fungal diseases can be transmitted by insects through the direct transfer of spores from infested to healthy trees. The bodies of insects emerging from diseased hosts become contaminated with the spores and when the insect attacks healthy trees, spores are introduced into the wounds. Viral, mycoplasmal, and rickettsial organisms are most often directly transmitted by species of sucking insects, such as leafhoppers. Wounds made by insects can indirectly serve as courts of entry for wind- and rain-borne spores.

Dutch elm disease is caused by the introduced fungus, *Ceratocystis ulmi* (Buisman) C. Moreau. The disease was first recorded in North America in Ohio in 1930, and by 1975 had been reported in all of the contiguous 48 States except Arizona, Florida, Louisiana, Nevada, New Mexico, and Utah *(1069)*. Both native and exotic species of elm are hosts for the disease, with the common American elm as its most susceptible host. Principal insect vectors are the smaller European elm bark beetle and the native elm bark beetle *(224, 274)*. Other insects carry spores of the fungus, but the life cycle of the elm bark beetle is ideal for disease spread. Adult beetles emerging from diseased trees carry spores to healthy parts of the same tree and to adjacent healthy trees where the beetles feed and lay eggs. The spores germinate in the feeding wounds and initiate new infections, which weakens the tree and aids the larval feeding *(1091)*. Much of the effort to control Dutch elm disease has involved insect control. Early efforts were made by using insecticides. Sanitation efforts have been more long lasting by reducing the opportunities for beetles to move the fungus. However, the common occurrence of elms has made this a costly method *(970, 1069, 1091)*.

The first symptoms of Dutch elm disease are wilting and yellowing or drying of foliage. Defoliation and death of the affected branches soon occurs. Diseased trees commonly die gradually, branch by branch, over a period of several months or even years. A brown discoloration in the water-conducting vessels develops in affected trees. In early spring, this occurs as brown streaks in the wood just under the bark of diseased branches (fig. 3). Later in the growing season, it appears as brown spots or as a partial or complete brown circle in one or more outer rings of the wood.

Elm phloem necrosis is a disease of American, slippery, cedar, winged, and September elms. It occurs in parts of Ohio, Indiana, Illinois, Missouri, Iowa, Nebraska, Kansas, Oklahoma, Arkansas, Mississippi, Alabama, Georgia, Tennessee, Kentucky, West Virginia, Pennsylvania, New York, and New Jersey. Evidence indicates the disease is not caused by a virus, as earlier suspected, but rather

by a mycoplasmal organism *(1315)*. Mycoplasmas are transmitted through root grafts, or by the whitebanded elm leafhopper *(43)* that is widely distributed in the Eastern United States. The leafhopper ingests the mycoplasma while feeding on the sap of a diseased tree. Later, the disease organism is transmitted when the insect feeds on a healthy tree.



Courtesy G. N. Lanier, SUNY Coll. Environ. Sci. & For., photo by George Snyder

Figure 3.—Elm twig with streaking symptomatic of Dutch elm disease.

Foliar symptoms of elm phloem necrosis vary but are somewhat similar to those produced by drought, girdling, and certain other tree diseases. Symptoms may first appear on a single branch or a portion of the top, but most often the entire tree is symptomatic. In large trees, there is usually an apparent thinning of foliage in the top or at the outer tips of branches. This is followed by a general thinning of foliage throughout the crown. Generally, the leaves become chlorotic but some leaves become dry and brown. Defoliation and tree death occasionally happen within 3 to 4 weeks but it usually requires from 1 to 1½ years. Before the tree dies, a typical yellow to butterscotch discoloration of the phloem develops (fig. 4). In large trees this discoloration is usually found only in large roots and the lower part of the trunk. In most small trees, and occasionally in large ones, it may be found in the upper part of the trunk and in branches. The butterscotch-colored phloem of American elm with elm necrosis has a faint odor of wintergreen, especially if the plant part is enclosed briefly in a bottle.

During ephiphytotics such as occurred in the Central States in the late 1930's and 1940's, elm phloem necrosis killed numerous valuable shade tree elms in many cities and towns (fig. 5). During the 1950's the disease was at a low ebb, but more recently the disease is again on the increase in New York, Ohio, and Pennsylvania.

Beech bark disease is a destructive disease of American and European beeches and all their varieties. It is caused by related fungi, *Nectria coccinea* var. *faginata* Lohman, Watson, & Ayres and *N. galligena* Bres. *(250)*. These pathogens gain entry into the tree through tiny ruptures in the bark caused by the feeding of the beech scale. The scale and probably the fungus are of foreign origin. The disease,

which was first recorded at Halifax, Nova Scotia, in 1920, now occurs throughout the Maritime Provinces of Canada, west to Quebec, and south through the beech-growing areas of New England to West Virginia *(847, 1080)*. Surveys indicate that the disease is moving south and west at a steady rate.

F-520108

Figure 4.—Typical discoloration of the phloem of an elm tree infected with elm phloem necrosis.

F-519951

Figure 5.—Shade tree elms killed by elm phloem necrosis mycoplasm.

The fungus may infect large areas on scale-infested trees, completely girdling and killing them. Trees only partially girdled may remain alive in a weakened state for many years unless broken by the wind. On some trees, the fungus is confined to strip or spot cankers on the bole. Parts of the crowns of these trees become chlorotic and die.

In many stands, beech bark disease has killed more than half the beech, and the commerical value of many of the survivors has been seriously reduced. Disease control has not been attempted; the presence of disease-free trees in the midst of heavy infestations suggests resistance in the host population *(1080)*.

Oak wilt disease, caused by the fungus *Ceratocystis fagacearum* (Bretz) Hunt, occurs over a wide area from Nebraska and Kansas to the Carolinas and Pennsylvania. The fungus attacks all native species of oak regardless of size, age, or vigor. Local spread from infected trees to adjacent healthy trees occurs through natural root grafts; insects, however, apparently are responsible for spread over longer distances. Oak bark beetles, *Pseudopityophthorus* spp., are recognized as being the most important vectors of the oak wilt fungus *(168, 506, 1021, 1022)*. In areas of the country where mycelial mats of the fungus develop on diseased trees, species of sap-feeding and mycophagus nitidulid beetles probably are vectors of the fungus *(323, 811)*.

Oak wilt is potentially a very serious disease (fig. 6). Given the proper conditions for an epiphytotic, it could cause heavy losses in the vast oak forests of the Eastern

United States, but it has not, probably because the vectors are not efficient transmitters of the disease. It has, however, caused considerable damage in many oak woodlots and forest stands in Wisconsin, Minnesota, West Virginia, and Iowa *(438)*. Control measures include sanitation by removal of infected trees and trenching between infected and healthy trees to eliminate root grafts.

Persimmon wilt is a fast-killing disease of common persimmon that occurs in the Southeastern States west to Texas and Oklahoma. It is caused by the fungus, *Cephalosporium diospyri* Crandall, which produces masses of spores beneath the bark of infected trees. In smooth-barked trees the spores occur in such large masses that the overlying bark is raised in the form of blisters. When these blisters break, the spores are released and then blown away by the wind. In rough-barked trees the spores are produced in the cambial region and are released when the bark begins to disintegrate or is removed or broken off.

Wind is undoubtedly the major agent of spore dissemination, but some spread is also probably effected by insects such as the bostrichid, *Xylobiops basilaris* (Say). The adults of this species, some of which attack healthy trees, become contaminated when they emerge through spore masses on dying trees. Feeding injuries on the terminals and twigs by adults of this twig girdler also serve as entry courts for windborne spores *(263)*.

Fungi that cause **blue stains** are introduced into pines by bark beetles, and the fungi kill trees *(65, 918)*. Blue stain occurs in felled timber, in beetle-infested trees, and in trees weakened by fire, drought, or other adverse factors.

F-519913

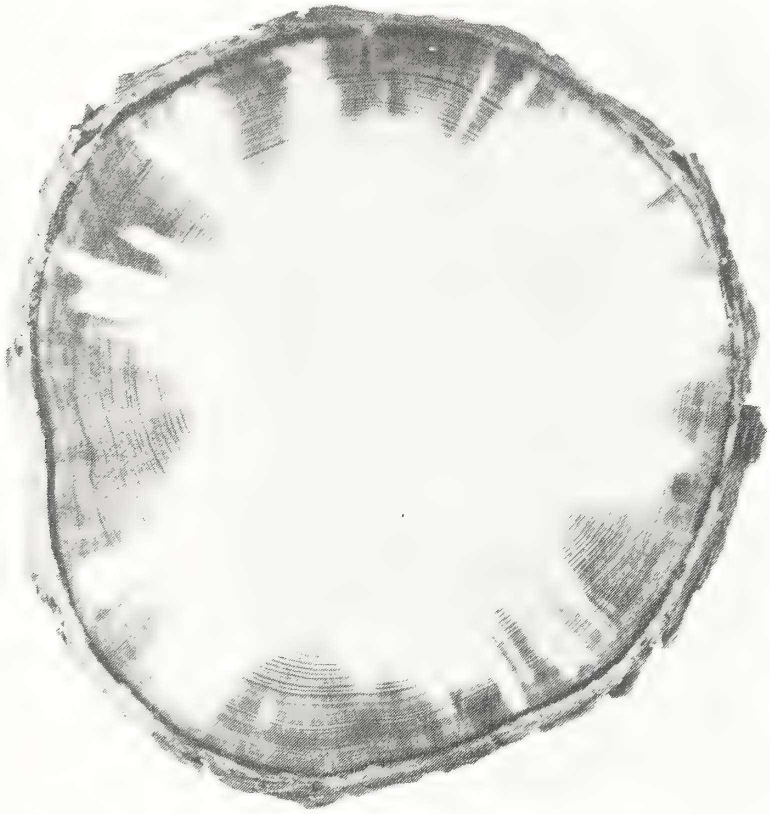
Figure 6.—Oak tree killed by the oak wilt fungus, *Ceratocystis fagacearum*.

Ceratocystis minor (Hedgc.) Hunt, one of the most important of the blue-stain fungi in the Eastern United States, is introduced into pine trees by the southern pine beetle. Blue-stain fungi interfere with normal water movement in the tree, and the tree shows wilt symptoms as it dies. The presence of blue stain in wood reduces its market value.

Ceratocystis ips (Rumbold) C. Moreau is introduced into southern pines by the engraver beetles, *Ips calligraphus* and *I. grandicollis,* and it produces a stain that spreads inward from the beetle galleries toward the heartwood (fig. 7). This fungus has also been found in living and felled red pines attacked by *I. pini* and *I. grandicollis* in the Lake States *(719).*

Several authors discuss the interrelationships of bark beetles and blue-stain fungi *(146, 917, 1044).* A number of species of ambrosia beetles carry staining fungi on their bodies and, because they attack hardwood logs and lumber in large numbers, are considered to be important disseminators of stain-inducing agents *(1231).*

The cyclic occurrence of **pitch canker disease** of slash and loblolly pines suggests that it is dependent on insects for spread *(351).* Pitch canker disease is caused by *Fusarium moniliforme* Sheld. var. *subglutinans* Wollenw. & Reink. Tip moth damage and pitch canker damage are sometimes associated. The deodar weevil feeds on young shoots in the upper crown of slash and loblolly pines, creating wounds, which are colonized by the pitch canker organism. Since spores of the fungus are wind- and water-borne, any insect-induced wound is probably used as a court of entry by the fungus.



Courtesy Duke Univ. Sch. For.

Figure 7.—Cross section of bole of shortleaf pine killed by *Ips calligraphus*, showing development of blue-stain fungus, *Ceratocystis ips*, in sapwood.

Insects and Related Organisms

No discussion of organisms that damage or destroy trees or forest products is complete without reference to some species of mollusks and arthropods other than insects. A number of others in the hierarchy of arthropods, such as crustacea, millipedes, centipedes, scorpions, spiders, mites, ticks, etc., are commonly encountered in woodland settings, so they are included in this book. Some species of mites, in particular, may damage, even destroy trees, while others are beneficial as predators of pest insects.

Phylum Mollusca—Shipworms

Wood submerged in salt water is attacked by several species of bivalve mollusks, commonly known as shipworms. These relatives of clams, mussels, and oysters can cause severe damage to pilings, especially along the Gulf Coast and along the Atlantic Coast south of the Chesapeake Bay. Boats are also damaged occasionally. These organisms are discussed briefly because the damage they cause is similar to and often confused with that caused by wood-boring insects.

The genera *Teredo* and *Bankia* contain the so-called shipworms. Their bodies are long and soft. They are armed with small, chisellike shells at the anterior end and there are two siphon tubes at the posterior end. They are free-swimmers in the early larval stage, and during this period the body is protected by a bivalve shell. Free-swimming larvae seek out wood and attach themselves to it near the mud line. Then they bore into the wood, leaving very small openings to the outside. Once inside they develop rapidly, enlarging and lengthening their tunnels as they grow. During this period when the shell is no longer needed for protection, it is used as a boring tool. As they develop, shipworms secrete a calcareous material with which they line their tunnels. The openings made by the young larvae are never enlarged. As a result, the only external signs of infestation of a piece of heavily damaged wood are tiny holes in its surface.

Because a single piling may contain several thousand shipworms, it may be literally honeycombed (fig. 8). In such situations, tunnels may be no more than 6 mm in diameter and only a few centimeters long. Under the most favorable conditions, however, the tunnels may reach a diameter of 2.5 cm and a length of 1.2 m.

The genus *Martesia* also contains a number of destructive species. They differ from the shipworms in being clamlike. The young are also free-swimmers and seek out and attack submerged wood, making small, inconspicuous entrance holes. Once inside the wood, they grow until they are approximately 25 mm in diameter and 60 mm long. As they grow, they enlarge their cavities to accommodate their bodies. Members of this genus are found along the shores of the Gulf of Mexico.

Damage to pilings by shipworms can be prevented by impregnating the wood with a suitable preservative. Coal tar creosote (American Wood-Preservers' Association specification) is recommended for treating waterfront timbers of Douglas-fir and southern pine. Copper naphthenate is usually used for the protection of wood in boats. Coatings of paint and metal are also effective as long as they remain intact.

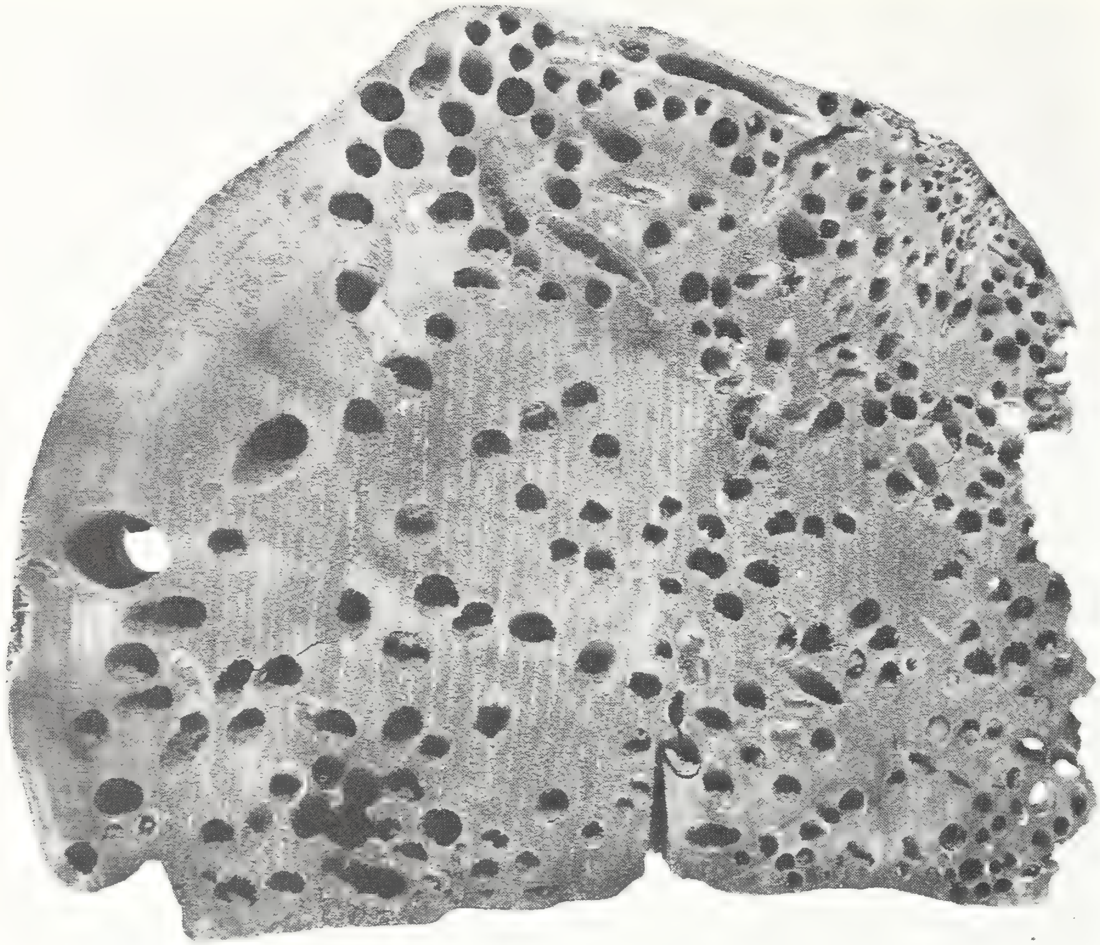


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Figure 8.—Cross section of a piece of timber riddled with tunnels made by a molluscan shipworm of the genus *Bankia*.

Phylum Arthropoda

Insects belong to the phylum Arthropoda, one of the major groups of the animal kingdom. In the hierarchy of animal phyla it stands near the top, far removed from the simplest, one-celled organisms in the phylum Protozoa. The phylum also contains many other well-known forms such as crawfish, shrimp, millipedes, centipedes, spiders, and mites. Members of the phylum are distinguished by a body that is composed of a series of more or less similar rings or segments joined together, some of which bear jointed legs. In certain forms, the segmentations of the body may be obscure and not evident from cursory examination. In most instances this is due to a secondary modification of form, a result of adaptation to special modes of life *(230)*.

Insects constitute the most abundant and important group of arthropods, but many other members of the phylum are also common and often important. Many of the latter are harmful, either to trees and other vegetation or to wildlife and humans. Many are so small they are seldom seen, although enormously abundant; other, larger ones, are easily seen. Some of the latter are also many-legged and wormlike and bear little or no resemblance to insects; others are often mistakenly identified as insects. The arthropods discussed here belong to the classes Insecta (insects), Crustacea (crawfish, shrimp, crabs), Diplopoda (millipedes), Chilopoda (centipedes), and Arachnida (spiders, mites, scorpions).

Class Crustacea—Wood Lice

Crustaceans are primarily marine organisms. They occur throughout the world, and several species attack the wood of most species of trees when the wood is placed in saltwater. The surface of heavily infested wood may be so completely honeycombed that it resembles a sponge. When this damaged wood is removed by wave action, deeper layers of uninfested wood are exposed. They, in turn, are attacked and the process of destruction is repeated. Continuous infestation may result in the loss of the outer 2 cm of wood per year. Infested pilings often have an hourglass shape as a result of the erosion of infested portions between low- and high-tide marks. Heaviest attacks occur between mean tide level and low tide, but serious damage sometimes occurs at water depths of 12 to 21 m or more *(21)*. In contrast, *Oniscus asellus* L., the **common terrestrial sowbug**, and related species are usually beneficial. In certain habitats they rapidly ingest decaying leaves and wood, releasing nutrients needed for plant growth.

Limnoria lignorum (Rathke), the **wood louse**, is one of the most destructive species. It has seven pairs of legs, sharp claws for holding onto the wood, and a pair of toothed mandibles for boring into it. Full-grown specimens are 3 to 6 mm long and resemble sowbugs. This species occurs in clear saltwater only and spreads slowly, usually in infested driftwood.

Members of the genus *Sphaeroma* are beetlelike in appearance and are up to 12 mm long. They occur in both salt and fresh water and may be found in such places as crevices, empty barnacle shells, and in burrows made by molluscan borers. They also damage pilings, usually between tide marks but sometimes all the way down to the mud line. Damage is usually less severe than that caused by *Limnoria*, even though the burrows are somewhat wider and penetrate to depths of 8 to 10 cm.

The genus *Chelura* contains the largest of the wood-boring crustaceans. None of these initiates attacks on wood, but they do invade and enlarge burrows made by shipworms. *C. terebrans* Philippi is a well-known species along the Atlantic Coast.

Methods for protecting timbers from wood-boring crustaceans are the same as those used against molluscan borers.

Class Diplopoda—Millipedes

Millipedes are slow-moving, elongate, wormlike organisms, usually with 30 or more pairs of legs. Generally they are found under bark, stones, old boards, or in damp rubbish. Their food consists of decaying vegetable matter. The adult has two body regions: (1) the head, which bears a pair of short antennae, usually seven-segmented; and (2) the rest of the body, which consists of a large number of similar cylindrical segments. The first four or five body segments are not fused, and each bears a single pair of legs. The remaining segments are fused into ringlike joints, each of which bears two pairs of legs. *Narceus americanus* (Beauvois), one of the larger species, is dark brown, narrowly ringed with red, and about 10 cm long.

Millipedes sometimes become abundant. At such times they may invade camps, old buildings, and residences in large numbers. Many species emit a fluid with a cyanidelike odor through openings along the sides of the body. Removal of moisture and of accumulations of vegetable matter from infested areas should be helpful in control of millipedes. Discussion of numerous species occurring in the Eastern United States may be found elsewhere *(1312)*.

Class Chilopoda—Centipedes

Centipedes are wormlike animals with elongate, flattened, segmented bodies. They have 15 or more pairs of strong legs, one pair per segment. The antennae have 14 or more segments, and the appendages of the first body segment behind the head are clawlike and function as poison jaws. The last two pairs of legs at the posterior of the body are directed backward. Centipedes are usually found under bark, in rotting logs, or under stones or boards. They are swift runners and feed on various small animals such as snails, insects, and spiders. All species possess poison jaws with which to paralyze their prey. They will also bite humans.

The largest centipedes belong to the family Scolopendridae, some of which may be more than 30 cm long. The largest species found in the United States, however, is only 12.5 cm long. Members of this family are also the most venomous of all centipedes. The bite of the largest ones is not only quite painful but also occasionally fatal *(140)*. The larger and more dangerous species are southern in distribution; those occurring in the North are usually too small to be harmful to humans. The centipedes of New York have been reviewed *(37)*.

The removal of debris used as hiding places is helpful in centipede control.

Class Arachnida—Scorpions, Spiders, Mites, Ticks, and Allies

The class Arachnida is a large group of air-breathing arthropods whose bodies usually comprise two regions: (1) the cephalothorax, and (2) the abdomen. They generally have six pairs of appendages (the chelicera, pedipalps, and four pairs of legs) but are without antennae.

Order Scorpiones—*Scorpions*

Scorpions are fairly common in the Eastern United States, especially in the South. However, because they are active only at night and usually remain hidden during the day, they are seldom seen. Indoors, they usually hide in such places as closets, attics, folded blankets, shoes, and papers. Scorpions vary considerably in size, ranging from about 1 to 18 cm long. The abdomen is divided into a large anterior portion of seven segments and a long, narrow taillike posterior portion of five segments. The latter ends in a vesicle that bears a poisonous sting. When a scorpion runs, it holds its large clawlike pedipalps forward, and the posterior end, bearing the sting, is usually curved upward.

Scorpions are capable of inflicting painful but rarely fatal stings. Very young and very old people appear to be the most vulnerable. Scorpions' food consists of a wide variety of animal life including other scorpions, spiders, flies, beetles, cockroaches, grasshoppers, crickets, termites, centipedes, and earthworms. A common species in many parts of the Eastern United States is *Centruroides vittatus* (Say), the so-called **striped scorpion** (fig. 9). This is a fairly small species, being only about 58 to 60 mm long. Its sting results in a sharp pain that usually lasts about 15 to 20 minutes. Stings inflicted from late March to early May, however, may remain painful for several hours *(36)*.

Scorpions may be trapped during dry seasons by spreading wet burlap bags on the ground in infested areas.

Order Pseudoscorpiones—*Pseudoscorpions*

Pseudoscorpions bear a striking resemblance to their larger relatives, the true scorpions, but differ in having wider, shorter abdomens and no terminal poison glands. They are seldom more than 5 mm long.

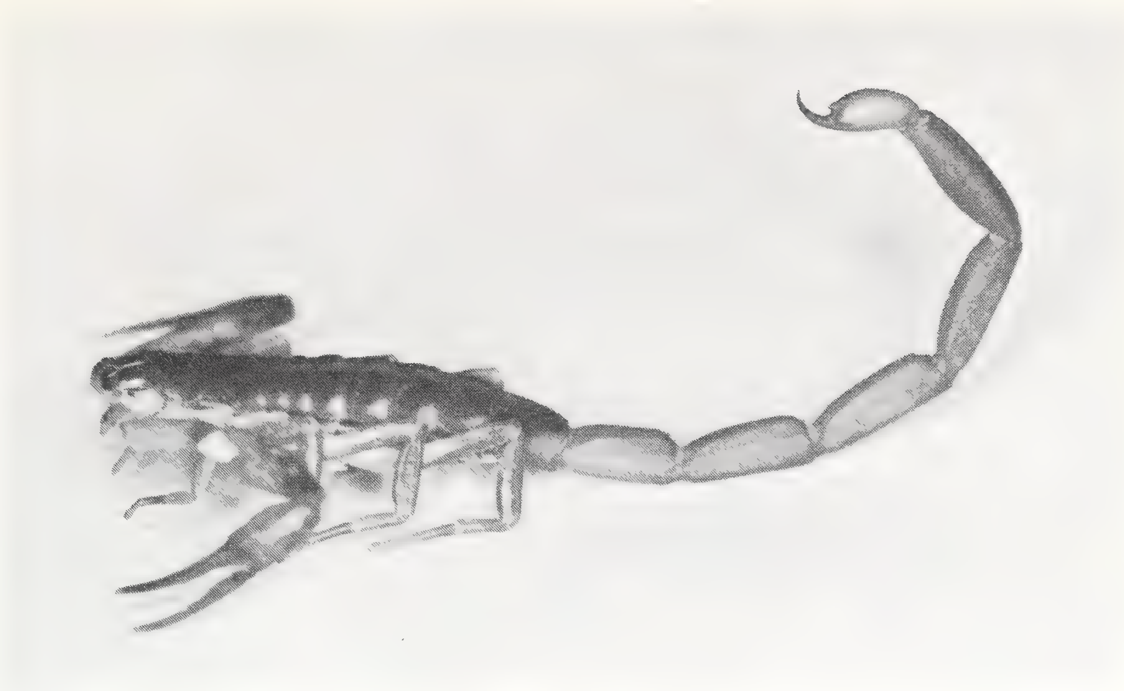

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Figure 9.—*Centruroides vittatus*, the striped scorpion.

Pseudoscorpions may be found in a wide variety of places—in soil cover, under bark, under the wings of beetles, on the bodies of birds and in their nests, in buildings, in chicken houses, and in beehives. Their food consists of mites, ants, and various other insects. One species, *Chelifer cancroides* (L.), is frequently found in association with humans. Adults are about 2.5 to 3 mm long *(582)*.

Order* Opiliones—*Daddylonglegs

Daddylonglegs are somewhat similar in appearance to spiders but differ in having small, compact, nearly globular bodies and extremely long legs. They also are rather slow in movement, usually appearing to totter about, and they occur commonly in most parts of the United States. Their food consists chiefly of plant juices or dead insects. Some apparently feed on living insects. When crushed, their bodies give off a disagreeable odor. None is harmful to humans.

Order* Araneae—*Spiders

Spiders are found almost everywhere, both indoors and outdoors, and are so familiar as to need no description *(229)*. Objects of fear and revulsion to many people, their presence in large numbers in and around places of habitation, or other areas frequented by people, is often considered intolerable. Fortunately, the majority of species pose no hazard to humans, even though all have venom glands. Actually, they generally are more beneficial than harmful since their food consists mainly of insects and other small organisms. A few species, however, are poisonous to humans and should be avoided *(35)*.

The **black widow spider**, *Latrodectus mactans* (F.), is probably the most poisonous spider in the United States. The effect of its bite is described as being extremely painful throughout all the muscles of the body, and it occasionally results in death. The black widow occurs from southern Canada southward through the United States, Mexico, Central America, and deep into South America. In the Eastern States it is most common in the South, but also occurs as far north as Maine.

Black widows are usually found in such places as garages, sheds, outdoor toilets, under rocks and old boards, and in hollow logs or animal burrows. The female is shining jet black and bears an hourglasslike red mark on the underside of the

abdomen. The body of a full-grown specimen is about 12 mm long exclusive of the long legs. Males are much smaller and are seldom seen.

The **brown recluse spider**, *Loxosceles reclusa* Gertsch and Mulaik, is also quite poisonous to humans, its bite producing a condition known as "North American Loxoscelism." Adults are about 9 mm long, have long legs, and vary from light fawn to dark brown. A distinguishing mark is a dark fiddle-shaped band on the anterior portion of the carapace, which narrows to a thin center line and extends almost to the abdomen. It is only within recent years that this species has been recognized as poisonous to humans. It has been recorded from the Southern and Central States. It may be found in almost any location where protection, food, and dryness are adequate, but it probably occurs most commonly inside buildings. Its web is medium-size and irregular, with a maze of threads extending in all directions without definite pattern *(573)*.

It is usually impractical or impossible to eliminate spiders completely. Populations can be reduced, however, by the removal of favorite breeding places.

Order* Acari—*Mites and Ticks

The order Acari contains a large number of important pests of plants, humans, and other animals. The majority are extremely small and seldom seen; others, such as the ticks, are large enough to be seen with the naked eye. Members of this order differ from other arachnids in having the mouth parts more or less distinctly set off from the rest of the body on a false head, and the body is never so divided that a distinct cephalothorax and abdomen are clearly recognizable *(39)*.

Mites.—Numerous species of mites feed on and weaken or kill a wide variety of valuable plants, including trees *(640)*. Many others attack humans and various other forms of animal life, often causing extreme irritation, and sometimes illness and death. A considerable number are either parasitic or predacious on various species of destructive insects and harmful species of their own kind *(780, 1076)*. Many others feed on dead materials of all kinds on the forest floor.

The family Tetranychidae *(465, 781)* contains a large number of species commonly known as spider mites, many of which are important pests of trees and shrubs. These mites vary from yellowish, greenish, orangish, and reddish to red, and all are less than 1 mm long. Infested leaf surfaces are usually covered with a fine netting of silk and spotted with tiny spherical eggs or broken egg shells. Heavily infested foliage may be discolored, disfigured, or killed.

The **spruce spider mite**, *Oligonychus ununguis* (Jacobi), feeds on a number of conifers, especially spruce, thuja, and some of the pines, and is widely distributed in the United States. Infested trees may become brownish gray and appear unhealthy, or they may be completely defoliated. It is considered the most destructive conifer-feeding mite known *(143)*. Outbreaks over large forested areas have been recorded. Periods of drought appear to be most favorable for population buildups. Outbreaks have also occurred following widespread spraying with DDT *(642)*. Young nursery stock and recently planted trees are especially subject to serious injury.

Oligonychus milleri (McGregor) feeds on pines throughout the South and North to Pennsylvania and the Lake States. Outbreaks covering millions of hectares have been recorded from North Carolina to Florida, in northern Louisiana and southern Arkansas, and in Mississippi and Texas. Young, open-grown, even-aged stands appear to be susceptible to severe attack.

Other important species in the genus *Oligonychus* include *O. bicolor* (Banks), long recognized as a pest of oaks, especially shade oaks, and sometimes injurious

to beech; the **southern red mite**, *O. ilicis* (McGregor), damages azalea and camellia; *O. aceris* (Shimer) is sometimes a serious pest of maples; *O. letchworthi* Reeves occasionally seriously injures hophornbeam; *O. newcomeri* (McGregor) often seriously infests serviceberry; *O. cunliffei* Pritchard & Baker feeds on longleaf pine in Florida; *O. boudreauxi* Pritchard & Baker feeds on baldcypress in the South; and *O. propetes* Pritchard & Baker feeds on oaks from Washington, D.C., to North Carolina.

The **carmine spider mite**, *Tetranychus cinnabarinus* (Boisduval), is a common and widely distributed species that feeds on a great many species of plants, trees, and ornamentals. Several generations are produced during the summer months, often giving rise to tremendous populations. Heavily infested plants may be entirely defoliated, especially during hot, dry weather. *T. homorus* Pritchard & Baker feeds on hickory and ash in North Carolina; *T. magnoliae* Boudreaux occurs on magnolia and yellow-poplar in Louisiana; the **fourspotted spider mite**, *T. canadensis* (McGregor), feeds on elm, basswood, horsechestnut, Osage-orange, and poplar throughout the Eastern United States and southern Canada; and the **Schoene spider mite**, *T. schoenei* McGregor, infests elm and black locust throughout the Eastern United States.

The genus *Eotetranychus* also contains a number of common and frequently important species. *E. populi* (Koch) and *E. weldoni* (Ewing) are found on poplars and willows; *E. hicoriae* (McGregor) occurs on pecan, hickory, horsechestnut, and various oaks; *E. matthyssei* Reeves attacks elm in New York. Heavy infestations may cause severe browning and cupping of the undersides of leaves. *E. querci* Reeves has caused severe browning of pin oaks in New York.

Platytetranychus multidigituli (Ewing) feeds on the leaves of honeylocust, causing them to turn yellow, and *P. thujae* (McGregor) attacks northern white-cedar, juniper, and baldcypress. *Eurytetranychus buxi* (Garman) is a serious pest of European boxwood. The leaves of infested plants become bronzed, then wither and sometimes fall prematurely.

The family Eriophyidae contains a number of tree-infesting species *(661)*. Many produce open pouchlike or blisterlike galls on the twigs and leaves of their hosts. Some cause a rusting of infested leaves, and certain others feed on buds. A few of the more common and important tree-infesting species are discussed here.

The **maple bladdergall mite**, *Vasates quadripedes* Shimer, is a common species. It ranges in length from about 0.05 to 0.2 mm and feeds on the undersurface of silver maple leaves, causing the formation of pouchlike or bladderlike galls up to 3 mm in diameter (fig. 10). At first, these galls are light colored or yellowish green. Later, they are reddish to almost black and look for all the world like miniature green peppers standing on stalks above the leaf surface. Heavily infested leaves are often distorted. The related species, *V. aceris-crummena* (Riley), produces slender, fusiform, or spindle-shaped galls about 5 mm long on the upper surfaces of silver and sugar maple leaves.

A few of the other eriophyids infesting trees and some of their hosts are as follows: *Eriophyes fraxiniflora* Felt feeds in the staminate flowers of ash. Infested clusters become deformed and remain on the tree as green masses until fall. The **pearleaf blister mite**, *E. pyri* (Pagenstecher), an introduced pest of pear and apple, also has been recorded on mountain-ash and serviceberry. It is sometimes abundant enough on mountain-ash to cause noticeable injury. *E. parapopuli* (Keifer) stunts the growth of poplar by producing woody galls around the buds. *E. caulis* Cook causes large, deforming, hairy growths on the petioles of black walnut leaves.

Acalitus phloeococotes (Nalepa) deforms fruit spurs and produces woody galls on plum. *Nalepella tsugifoliae* Keifer has been reported to damage hemlock in nurseries in New York. The **pine bud mite**, *Trisetacus pini* (Nalepa), causes the yellowing and dropping of pine needles. *T. cupressi* (Keifer) attacks southern redcedars, causing distortion and deformation of young trees.

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Figure 10.—Galls of the maple bladdergall mite, *Vasates quadripedes*, on leaf of maple.

Mites of the family Sarcoptidae are skin parasites of warm-blooded animals. The **itch mite**, *Sarcoptes scabiei* (De Geer), is a well-known species. It attacks humans and causes severe itching as it burrows into the skin.

The family Trombiculidae contains the notorious redbugs or chiggers. The common chigger in the Eastern United States is the first instar of the species, *Eutrombicula alfreddugesi* (Oudemans). In its later stages, it feeds on insects, snakes, birds, lizards, and rodents. When it attaches itself to the skin of humans and insects, it inserts its mouth parts to feed, causing intense itching and sores. Heavy attacks may cause fever, and secondary infections may occur. Chiggers are often abundant in the forests of the Central and Southern States and along the Atlantic seaboard north to New Jersey.

Many other species of mites occur in association with bark beetles *(891)*, and some are known to be parasitic. So far, very little information is available on their effectiveness in natural control of the beetles. In some instances, it may be substantial.

Ticks.—Ticks are all parasitic, chiefly on mammals, birds, and reptiles. All American species have a number of features in common, such as large size, a piercing hypostome with recurved teeth, and chelicera with lateral teeth on the movable digits. Some ticks are mostly covered by a hard dorsal plate called the scutum; in others, this hard plate is absent.

The **American dog tick**, *Dermacentor variabilis* (Say), occurs throughout the Eastern United States, but is most abundant in coastal areas and in the Mississippi River Valley. The larvae and nymphs feed largely on rodents; the adults feed on

dogs, horses, hogs, cattle, and many species of wild animals. Humans also may be bitten, but they are not a preferred host *(777)*. Unfed adults are brown, variously marked with white, and about 5 mm long. Engorged females are bluish gray and sometimes reach a length of 12 mm. Females lay eggs in various places but never on the host; the young seek out their host after hatching. Heaviest infestations are usually found on vegetation along game trails, paths, and roadways. Adults are most abundant during spring and early summer in the North. After August they are usually very scarce. In the South, they occur throughout the year. This species transmits Rocky Mountain spotted fever and tularemia, both serious diseases of humans. It also transmits anaplasmosis, a disease of cattle.

The **blacklegged tick**, *Ixodes scapularis* Say, occurs along the Atlantic Coast. The larvae and nymphs feed on rodents and reptiles, and the adults feed on deer, cattle, sheep, dogs, and other large animals. People are also bitten. This species has long mouth parts and inflicts a very painful bite. Infestations are usually found on vegetation along game trails, paths, and roadways where people and other animals come by. Adult ticks are most prevalent during fall and early winter. This species transmits anaplasmosis to cattle and piroplasmosis to dogs *(1219)*.

Class Insecta—Insects

An insect is an air-breathing arthropod with a distinct head, thorax, and abdomen. It has one pair of antennae, three pairs of legs, and usually one or two pairs of wings in the adult state. The majority of species are terrestrial and are found in an almost endless variety of microhabitats on the land. Many other species spend part of their lives in water.

The majority of insects hatch into wormlike larvae that grow by periodically shedding the outer skin, finally transforming into an inactive pupal stage from which the adult emerges. This type of development is known as complete metamorphosis. The immature stages of some others are very similar in appearance to the adults and are known as nymphs. Members of the latter group are said to have simple or incomplete metamorphosis.

Approximately 900,000 species of insects have been described. These species represent 80 to 90 percent of all the known kinds of animals. The actual number of insect species, however, is believed to be much larger and to run into the millions *(1048)*. Countless numbers feed on plants of all kinds, attacking all parts from the roots in the ground to the flowers and seeds in the tops. Thousands of others feed on other insects or other animals, including people.

Fortunately for humans and their interests, the majority of insects are either innocuous or beneficial. The remainder, unfortunately, include some of our most important enemies—not only do they feed on humans and other animals and often transmit deadly or debilitating disease organisms, but they also devour crops and decimate forests. Because of their abundance, their fantastic reproductive powers, and their remarkable capacities for adapting to changing conditions, insects present a continuing challenge to us in our efforts to limit their numbers to tolerable levels.

Several general references to insects are available for consultation *(140, 155, 165, 230, 386, 625, 728, 828, 1043)*.

Keys to the Orders and Families of Forest Insects and Allies, Based on Types of Injury

The following keys are designed for the use of those unfamiliar with the orders and families of insects. They are first separated into primary divisions according to the portions of trees attacked, the size of the trees, and the timber products infested. These main divisions are in turn subdivided into other groups or subdivisions.

Primary Divisions of Key

I. Insects injurious to seeds, seedlings, small reproduction, and young plantations.
   - A. Seeds, cones, and fruits.
   - B. Seedlings and small reproduction.

II. Insects, etc., injurious to large living trees and to small trees more than 1 or 2 meters tall.
   - A. Yellowing foliage.
   - B. Defoliators, leafminers, etc.
   - C. Twig and tip damage, etc.
   - D. Borers in wood and bark.
   - E. Galls, swellings, etc.
   - F. Sucking insects.

III. Insects injurious to forest products.
   - A. Defects in green timber.
   - B. Insects in round logs.
   - C. Insects in lumber.
   - D. Insects in wood in ground.
   - E. Defects in wood in salt and brackish water.

Division I
Insects Injurious to Seeds, Seedlings, Small Reproduction, and Young Plantations

This group includes the insects that attack the seeds, cones, and fruits of forest trees, and young seedlings in the nursery, plantation, or forest. Insects attacking trees more than 4 or 5 years old (large reproduction, forest and shade trees) are discussed under Division II.

A. Insects Attacking Seeds, Cones, and Fruits

1. Larvae without well-developed head capsule; maggotlike:
   With a sclerotized structure like a "breastbone" near anterior end; in seeds of fir, baldcypress, birch, and fruit of chokecherry ..... **Diptera**, Cecidomyiidae
   Without "breastbone"; mouth parts well developed; in fruits of cherry, apple, plum, hawthorn; in berries of dogwood, holly, and others; and in walnut husks .... **Diptera**, Tephritidae
   Larvae with distinct head capsule 2

2. Larvae active; body extended; abdominal prolegs present 3
Larvae less active; no abdominal prolegs; body curved 4
3. In the shucks of pecans, hickories, and walnuts and in acorns. . . . . **Lepidoptera**, Blastobasidae, Tortricidae
In cones . . . . **Lepidoptera**, Pyralidae
In fruits of wild cranberries and blueberries . . . **Lepidoptera**, Pyralidae
4. In acorns, walnuts, chestnuts, hickory nuts, and filberts 5
In leguminous seeds . . . . **Coleoptera**, Bruchidae
In cones 6
5. First abdominal spiracle vestigial; body spindle-shaped . . **Hymenoptera**, Cynipidae
First abdominal spiracle normal; body curved like a closed finger . . . . **Coleoptera**, Curculionidae
6. Cones abnormal and dropping prematurely . . . . **Coleoptera**, Scolytidae
Cones maturing; damage to seeds alone
Larvae legless . . . . **Hymenoptera**, Chalcididae
Larvae with true legs . . . . **Coleoptera**, Anobiidae

B. Insects, etc., Attacking Seedlings and Small Reproduction

7. Plants cut off near ground line or stems lacerated and shriveled 8
Plants wilting or fading, easily plucked from ground because of severed stem or roots below ground 9
Gall-like swellings on the stem 10
Bark gnawed in patches along the stem of conifers 11
Foliage off-color, yellowish or rusty, and often covered with very fine cobweblike threads or matting . . . . **Acari**, Tetranychidae
Roots showing small cottony or globular objects at time of transplanting . . . . **Homoptera**, Aphididae
Leaves or cotyledons cut off and carried away; Southern States . . . . **Hymenoptera**, Formicidae
Other types of damage. See Division II.
8. Small, tender plants:
Small, legless, maggotlike larvae causing injury . . . **Diptera**, Muscidae
Large, smooth, dark-colored caterpillars with legs and prolegs present . . . . **Lepidoptera**, Noctuidae
Larger plants, hardwoods, with woody part tunneled:
Tunnels longitudinal . . . . **Coleoptera**, Cerambycidae
Tunnels across the grain, wood stained . . . . . **Coleoptera**, Scolytidae
Tunnels irregular, chiefly underground . . . . **Isoptera**
9. Curved, grublike larvae in the soil . . . . **Coleoptera**, Scarabaeidae
Elongate, cylindrical, hard-shelled larvae . . . . . **Coleoptera**, Elateridae
Small, molelike tunnels usually near the surface of the soil . . . **Orthoptera**, Gryllotalpidae
10. Bark swollen and gnarled at or just below ground line
Mining damage . . . . **Lepidoptera**, Pyralidae
Sucking damage . . . . **Homoptera**, Fulgoridae
Nearby anthill . . . . **Hymenoptera**, Formicidae
11. Northern, Southern, and Lake States . . . . . . **Coleoptera**, Curculionidae
Southern and Lake States . . . . **Orthoptera**, Acrididae

Division II

Insects, etc., Injurious to Large Living Trees and to Small Trees More Than 1 or 2 Meters Tall

This group includes insects and related organisms that commonly attack living forest and shade trees but excludes those that attack fruit and seeds or that attack small plants not more than 4 or 5 years old. Insects responsible for damage to wood products, many of which primarily inhabit dead or dying trees or which attack logs, lumber, and other wood products, are discussed under Division III.

Injury consisting of discolored, yellowish, rusty, or mottled foliage covered with fine cobweblike threads or matting .... A
Injury consisting of defoliation, leaf rolling, leaf tying, leaf and petiole mining, or bast or epidermis miners on green-barked stems .... B
Injury occurring on new growth, twigs, branches, or small trees, consisting of mining, pruning, withering, or flagging C
Injury caused by larvae or beetles boring in the bark, under the bark, or in the wood .... D
Injury consisting of a gall or swelling on stem, branch, or leaf .... E
Injury caused by sucking insects feeding on leaves, twigs, or bark surfaces, usually the softer tissues of the plant .... F

A. Yellowing Foliage

Injury consisting of discolored, yellowish, rusty, or mottled foliage covered with fine cobweblike threads or matting .... **Acari**, Tetranychidae

B. Defoliation and Other Injury

1. Injury caused by beetles and/or larvae 2
   Injury caused by larvae 4
   Injury caused by other types of insects or insect not present 5
2. Adults and larvae associated on the leaves... **Coleoptera**, Chrysomelidae
   Adults only present 3
3. Beetles usually found feeding at night ..... **Coleoptera**, Scarabaeidae
   Small, bright-colored jumping beetles .... **Coleoptera**, Chrysomelidae
   Dull black, purplish, or gray, soft-bodied beetles.. **Coleoptera**, Meloidae
   Small snout beetles .... **Coleoptera**, Curculionidae
4. Prolegs, usually two or five pairs .... **Lepidoptera**
   Prolegs, usually six or more pairs—or none .... **Hymenoptera**, Tenthredinidae
   Prolegs inconspicuous; leaf- or bast-mining forms[2]
5. Circular holes cut in the leaves .... **Hymenoptera**, Megachilidae
   Trees defoliated, ant mounds nearby; Texas, Louisiana .. **Hymenoptera**, Formicidae
   Leaves rolled into a small, compact bundle **Coleoptera**, Curculionidae

[2] There seems to be no simple and practical method of separating the leafminers of the four orders that have species with this habit. Those found in conifers are probably either Lepidoptera or Hymenoptera; those on hardwoods may be Lepidoptera or Hymenoptera, or of the families Curculionidae, Chrysomelidae, or Buprestidae of the Coleoptera; or they may be Diptera of the families Agromyzidae or Cecidomyiidae.

Grasshoppers associated with injury .... **Orthoptera**, Acrididae
Walkingsticks associated with injury .... **Orthoptera**, Phasmatidae

C. Twig Pruning and Other Injury

6. Injured portion hollowed or mined; injury caused by larvae or bark beetles, which are usually present 7
   Injury caused by external feeding or ovipositing, which removes a portion of the bark or causes a definite mechanical injury or a resin-infiltrated scar 13
   Cottony masses on tops of twigs concealing the insects; conifers ..... **Homoptera**, Coccidae, Phylloxeridae
7. Injury on two or more whorls of the terminal of conifers; inactive, curved larvae under bark or in pupal cells in wood........**Coleoptera,** Curculionidae
   Twigs or branches of hardwoods or conifers containing bark beetles or powderpost beetles or a cylindrical shotlike hole, usually darkly stained, directly entering injured portion .... **Coleoptera**, Scolytidae, Bostrichidae
   Other injury 8
8. Twigs not mined below fading portion 9
   Twigs mined far below fading portion, tunnel often extending to the ground .... **Coleoptera**, Cerambycidae
9. Conifers 10
   Hardwoods 11
10. Larvae with prolegs; often pitch masses at point of injury .. **Lepidoptera**, Olethreutinae
    Larvae without conspicuous prolegs; usually a spine on last segment .... **Hymenoptera**, Siricidae
11. Larvae with well-developed prolegs; usually colored; usually in more tender parts of twigs ...... **Lepidoptera**, Olethreutinae, Sesiidae, Cossidae
    Larvae with underdeveloped prolegs; in woody portions of twigs 12
12. Elongate, flat larvae; mines filled .... **Coleoptera**, Buprestidae
    Cylindrical larvae; mines open .... **Coleoptera**, Cerambycidae
13. Obvious scar and pitching of wood at base of injury or along twigs; conifers
    Scale bodies present on twig .... **Homoptera**, Margarodidae
    Scale bodies absent .... **Coleoptera**, Cerambycidae
    Numerous phloem scars on twigs; spittle masses may be present ... **Homoptera**, Cercopidae
    (Hail injury is similar except that the scars are always on top side of branch)
    Twigs slit with a lacerated wound at base of injury or at point of breaking .... **Homoptera**, Cicadidae, Membracidae **Orthoptera**, Gryllidae

D. Borers in Wood and Bark

14. Borers in the phloem and outer corky bark of living trees rarely scarring the wood 15

Borers in callous tissue around wounds
On various hardwoods . . . . **Coleoptera**, Curculionidae
On maples . . . . . **Lepidoptera**, Sesiidae **Coleoptera**, Cerambycidae
On conifers . . . . **Lepidoptera**, Sesiidae, Pyralidae
Borers in the dead wood beneath fire scars, turpentined faces, blazes, cavities, and similar wounds 16
Borers under the bark or in the wood (other than beneath scars or catfaces) of living trees 17
Bark beetles associated with their larvae under the bark . . . . **Coleoptera**, Scolytidae
Root borers or mining at base of tree 22

15. White, unpigmented larvae . . . . **Coleoptera**, Cerambycidae
Highly pigmented larvae in galls . . . . . . **Hymenoptera**, Tenthredinidae
Serpentine mines just under the epidermis of chestnut and oak . . . . **Lepidoptera**, Nepticulidae

16. Beetle larvae; wood stained around holes . . . **Coleoptera**, Scolytidae, Platypodidae
White, fleshy, cylindrical larvae in hardwoods . . . . **Coleoptera**, Cerambycidae, Brentidae
White, fleshy, flat-headed larvae in turpentined faces in fire scars on conifers . . . . **Coleoptera**, Buprestidae
Larvae with heavy, chitinous armature on last segment; chestnut, oak, maple . . . . **Coleoptera**, Lymexylonidae

17. Larval mines extended under the bark and also deep into the wood in later stages 18
Larval mines entirely under the bark or only in wood of current annual ring 21

18. Pitch exuding from larval mines; larvae with prolegs present; conifers . . . . **Lepidoptera**, Sesiidae, Pyralidae
No pitch, but often water and frass exuding 19

19. Head of larvae globular, protuberant 20
Head of larvae somewhat flattened and embedded in prothorax . . **Coleoptera**, Cerambycidae

20. Prolegs absent; last segment often heavily armed . . . . **Coleoptera**, Tenebrionidae
Prolegs absent; larvae curved, grublike; in willow, poplar, and palmetto . . . . **Coleoptera**, Curculionidae
Prolegs present; last segment not heavily armed . . . **Lepidoptera**, Hepialidae, Sesiidae

21. Larvae depressed, flat-headed or pestle-shaped . . **Coleoptera**, Buprestidae
Larvae curved, grublike . . . . **Coleoptera**, Curculionidae
Larvae slender; thoracic segments not noticeably enlarged; cause pitch flecks in wood; birch, etc. . . . . **Diptera**, Agromyzidae

22. Larvae with prolegs; poplar, willow, alder, ash, persimmon . . . . **Lepidoptera**, Hepialidae, Sesiidae
Larvae without prolegs
In hardwoods . . . . **Coleoptera**, Cerambycidae
In conifers; associated with pitch mass . . . **Coleoptera**, Curculionidae, Scolytidae

E. Galls[3]

23. Galls of more or less open, exposed, simple structure, or, when enclosed, the insects maintain permanent openings, or the galls are dehiscent to permit the escape of the numerous insects inhabiting them 24
    Galls usually completely enclosing the inhabitant; one or, rarely, several insects to a cavity; occasionally a permanent opening is maintained by the feeding larva 27
24. Mites present having two pairs of legs; galls of various shapes but always provided with an opening to the exterior and lined on the inside with hairy or fuzzy growths .... **Acari**, Eriophyidae
    Galls otherwise 25
25. Insects not fitted for jumping 26
    Insects with hindlegs developed for jumping ... **Homoptera**, Psyllidae
26. Leaf galls on hardwoods, chiefly elm, poplar, hickory, ash, sumac, and witch-hazel .... **Homoptera**, Aphididae
    Conelike galls on tips of spruce twigs ..... **Homoptera**, Phylloxeridae
    Pitlike galls on twigs of hard pines .... **Homoptera**, Margarodidae
    Pitlike galls on twigs of white oak ..... **Homoptera**, Asterolecaniidae
27. Galls inhabited by larvae with well-developed head capsules 28
    Larvae without well-developed head capsules, maggotlike; white to yellowish or reddish in color:
    Larvae with a distinct structure like a "breastbone" near anterior end .... **Diptera**, Cecidomyiidae
    Larvae without "breastbone"; mouth parts well developed .... **Diptera**, Agromyzidae
28. Larvae legless or with only minute legs 29
    Legs well developed, also prolegs present 30
29. Woody galls containing plain evidences of mining activity of the larvae; larvae with well-developed head capsules and mandibles . **Coleoptera**, Buprestidae, Cerambycidae, Curculionidae
    Larval mines not obvious; white larvae, curved or grublike in form, legless, and with distinct head capsule, each contained in a specialized cell .... **Hymenoptera**, Cynipidae, Chalcididae
30. On willow .... **Hymenoptera**, Tenthredinidae
    On locust, poplar, maple .... **Lepidoptera**, Tortricidae

F. Sucking Insects

31. Injury or insects present on leaves 32
    Injury primarily confined to twigs 33
    Injury primarily confined to branches and main stem 34
32. Leaves off-color, yellowish or spotted from feeding punctures of active, jumping insects .... **Homoptera**, Cicadellidae **Hemiptera**, Tingidae
    Leaves bearing galls or abnormal spots:
    On hackberry .... **Homoptera**, Psyllidae

[3] It seems impossible to devise a key that will separate all the varied types of galls into family or order groups. However, many groups are fairly true to type and, if considered with the larvae or other stages of the insect inhabiting them, you can make a fairly workable distinction.

On elm, poplar, willow, witch-hazel, hickory, oak, chestnut, etc. .... **Homoptera**, Aphididae, Phylloxeridae

On conifers .... **Homoptera**, Phylloxeridae

Exposed insects on the leaves:

Scalelike, gall-like, or soft grublike insects covered with wax in the form of powder or tufts .... **Homoptera**, Coccidae

Fringed, scalelike immature forms associated on the leaves with white four-winged "flies" .... **Homoptera**, Aleyrodidae

Soft-bodied insects with long conspicuous antennae . **Homoptera**, Aphididae

33. Insects surrounded by a conspicuous frothy mass of spittle:

Ends of branches and trees slowly dying in severe infestations, numerous small resin-soaked spots in inner bark and twig wood; pines .... **Homoptera**, Cercopidae

Injury consisting of ragged slits in the twigs, often breaking at incision; the tops of the branches hanging with withered leaves; hardwoods .... **Homoptera**, Cicadidae, Membracidae

Injury consisting of gall-like or gouty swelling on limbs and twigs of firs .... **Homoptera**, Phylloxeridae

Tips of hard pines flagged (needles yellowing); scales embedded in pits in bark .... **Homoptera**, Coccidae

Branches and twigs infested with scalelike, gall-like, or soft-bodied insects covered with waxy powder or tufts; twigs often dying ...... **Homoptera**, Coccidae

Tips of branches swollen forming pineapplelike galls .... **Homoptera**, Phylloxeridae

Tips of new growth withering, infested with numerous soft-bodied insects with prominent antennae .... **Homoptera**, Aphididae

34. Fir trees unhealthy and dying; trunks infested with masses of soft-bodied insects appearing as a whitish wool .... **Homoptera**, Phylloxeridae

Beech trees unhealthy and slowly dying, with dead areas of bark on stems covered with whitish masses of soft-bodied insects .... **Homoptera**, Margarodidae

Trees infested with scalelike, gall-like, or soft grublike insects, and covered with wax in the form of powder or tufts ...... **Homoptera**, Coccidae

Division III

Insects Injurious to Forest Products

This group includes insects causing the type of injury seen in the handling of forest products, i.e., logs and lumber, poles, posts, piling, and manufactured materials such as handles, gun stocks, stored wood, and wood in buildings. Certain types of damage found in green logs or freshly sawed lumber are the result of insects boring in the phloem or wood of the living tree. These are also treated here for convenience. They are usually distinguishable by the more or less stained condition of the surrounding wood, pitch infiltration, or the presence of scar (callous) tissue.

Defects occurring in the wood of green logs or lumber, revealed as the logs are sawed, usually as darkly stained, pitch-infiltrated wood, or scar (callous) tissue .... A

Injury occuring to material having the bark present (lumber excepted), such as round logs after the trees are felled and left either in the woods or at the mill, or logs utilized for rustic work, etc. . . . . B
Injury to freshly sawed lumber, seasoned lumber, stored and manufactured materials, or wood in buildings C
Injury to materials in contact with the ground, such as crossties, posts, poles, foundation materials, piling above water, etc. . . . . D
Defects in wood in salt and brackish water . . . . E

A. Defects in Green Timber

1. In hardwoods 2
   In conifers 5
2. Holes small, "pinholes," 6 mm or less in cross section; circular, open, i.e., never filled with boring dust 3
   Holes larger, "grub holes," up to 19 mm in diameter, usually oval in cross section, usually open, not filled with boring dust 4
   Pith flecks in wood; birch, maple, etc. . . . . **Diptera**, Agromyzidae
3. Pinholes, about 3 mm in size, of uniform diameter throughout, wood stained in streaks, in oaks and yellow-poplar **Coleoptera**, Scolytidae
   Holes tapering, several sizes grouped together and originating in a wound:
   Holes up to 6 mm in diameter, in American chestnut and chinkapin . . . . **Coleoptera**, Lymexylonidae
   Holes up to 3 mm in diameter, in oak and other woods . . . **Coleoptera**, Brentidae
4. Variable-size holes grouped and radiating from wounds or cavities . . . . **Coleoptera**, Cerambycidae, Tenebrionidae, Brentidae
   Large grub holes, up to 25 mm in diameter, usually appearing singly and not associated with wounds:
   In hickory . . . **Coleoptera**, Cerambycidae **Lepidoptera**, Cossidae
   In poplar and cottonwood . . . **Coleoptera**, Cerambycidae **Lepidoptera**, Cossidae, Sesiidae
   In maple . . . . **Coleoptera**, Cerambycidae, Tenebrionidae **Lepidoptera**, Cossidae, Sesiidae
   In ash . . . . **Lepidoptera**, Sesiidae
   In persimmon . . . . **Lepidoptera**, Sesiidae
   In locust . . . . . **Lepidoptera**, Cossidae **Coleoptera**, Cerambycidae
5. Pitch pockets in the wood . . . **Lepidoptera**, Sesiidae, Pyralidae **Coleoptera**, Scolytidae
   Holes filled with boring dust, associated with turpentine faces or fire scars:
   In the South, pines . . . . **Coleoptera**, Buprestidae
   In the North, pines or other conifers . . . . **Coleoptera**, Cerambycidae, Buprestidae

B. Insects in Round Logs

6. Sawdust exuding from small, round "pinholes" (2.5 mm or less in diameter) on the surface of the bark; wood usually stained around the holes . . . . **Coleoptera**, Scolytidae

Sawdust exuding from larger holes; larvae present under the bark or in wood . . . . **Coleoptera**, Cerambycidae

Sawdust not exuded; the only evidence of work is the presence of larvae or galleries under bark or in the wood:

Larvae elongate, cylindrical . . . . **Coleoptera**, Cerambycidae

Larvae flat-headed . . . . **Coleoptera**, Buprestidae

Larvae curved, legless; only one larva to a burrow . . . **Coleoptera**, Curculionidae

Larvae curved, legless; several larvae in a burrow, each usually separated by a pith or clay partition across the gallery . . . **Hymenoptera**, Sphecidae, Vespidae, Apidae

Larvae and bark beetles associate . . . . **Coleoptera**, Scolytidae

C. Insects in Lumber

7. Fine sawdust exuding from small "pinholes" (less than 2.5 mm in diameter) in green lumber; holes usually darkly stained . . **Coleoptera**, Scolytidae

Sawdust, if exuding, coming from larger holes in drier lumber, cut a month or more 8

8. Damage to lumber with bark present:

Larvae elongate . . . . **Coleoptera**, Cerambycidae

Larvae curved . . . . **Coleoptera**, Bostrichidae

Damage not associated with presence of bark on material 9

9. Fine sawdust exuding from circular or oval holes:

Small, curved larvae . . . . **Coleoptera**, Lyctidae

Elongate larvae . . . . **Coleoptera**, Cerambycidae

Large, black ants associated with damage; sawdust accumulating in large piles from damp wood . . . . **Hymenoptera**, Formicidae

Damage concealed and sawdust usually not falling from holes 10

10. Larval tunnels packed with sawdust:

Larvae elongate, cylindrical . . . . **Coleoptera**, Cerambycidae

Larvae elongate, flat-headed . . . . **Coleoptera**, Buprestidae

Tunnnels open:

Irregular cavities following the grain of the wood loosely filled with fine impressed pellets . . . . **Isoptera**

Round holes 12 mm or less in diameter, often with cross partitions or cells . . . . **Hymenoptera**, Apidae, Vespidae, Sphecidae

D. Insects in Wood in Ground

11. Large, elongate larvae associated with damage consisting of grub holes extending through the wood . . . . **Coleoptera**, Cerambycidae, Oedemeridae

Large irregular cavities eaten in the springwood, usually extending with the grain of the wood; sides of cavities plastered with claylike excrement . . . . **Isoptera**

Large, irregular cavities eaten into wood, usually cutting across grain, surfaces smooth, no excrement, large piles of sawdust accumulating outside; large, black ants associated with injury in moist or damp wood . . . . **Hymenoptera**, Formicidae

12. Pilings with spongelike damage resulting in hourglass shape due to wood erosion between low and high tide .... **Crustacea**, Limnoriidae
13. Pilings or other wood with holes showing calcareous shells in holes .... **Gastropoda**, Teredinidae

Important and Selected Orders of Forest Insects

The major section of this book, which follows, discusses the most important insects affecting forest and shade trees, shrubs, and wood products. The discussion includes brief descriptions of the insects and their habits, primary hosts, economic impact on forests, and possible control measures. Also included are a number of other insects that are abundant in the forest but usually are not thought of as forest insects. Given the ever-increasing use of forested areas for recreational purposes and the growing public concern about our wildlife resources, it seems appropriate to include such insects and describe their importance as pests of humans or other forms of animal life.

Order Thysanura—*Bristletails*

Bristletails occur abundantly in the forest in rotting wood and debris, under stones, and among fallen leaves, but none is injurious. They are distinguished by the stylelike appendages on some of the abdominal segments, by the two or three taillike appendages at their posterior ends, and usually by their elongate bodies.

Order Collembola—*Springtails*

Springtails are very small, primitive, wingless insects. The body is covered by a soft exoskeleton and there is a single pair of antennae, each normally consisting of four segments. The mouth is located ventrally, and the mandibles and maxillae are either toothed for chewing or styliform for sucking. There are three pairs of legs, each typically terminating in one or two claws. The first abdominal segment bears a ventral tube or collophore; there is a pair of small appendages fused basally on the venter of the third segment; and a furcula is appended to the ventral surface of the fourth. The latter operates as a spring and is capable of propelling the insect into the air as much as 10 cm *(835)*.

Springtails are widely distributed and are among the most abundant of insects. They are found in all kinds of places—many unexpected, such as on the surface of snow and on the surface of water. In the forest they are found in moist soil, among dead leaves, in dead and decaying logs, under loose bark, and in bark crevices of living trees. The majority feed on algae, fungi, and lichens and other living or dead plant matter. Pollen from conifers is favored by some species in the spring. Some may be attracted in large numbers to decaying fruit and animal matter. Others may be attracted to sap flowing from trees in the spring.

Springtails tend to be beneficial in the forest because they help to reduce litter and form humus. Keys to Collembola occurring in eastern North America are available *(88, 429, 835, 862, 1359)*.

Order Ephemeroptera—*Mayflies*

Mayflies are frail, delicate insects with medium-size soft bodies that end in three long threadlike tails, or caudal setae. The wings are membranous and many-veined and are held upright while at rest. The front pair is large and triangular; the hind

pair, when present, is small and rounded. The antennae are bristlelike and inconspicuous; the mouth parts, vestigial. The nymphs are elongate and cylindrical or flattened, and have leaflike gills along the sides of the body. In most species the gills have three long tails.

Mayfly nymphs live under stones or among debris on the bottom of streams where they feed on decaying vegetable matter, algae, and diatoms. When they become full grown they leave the water and transform to adults on nearby vegetation. The adults occasionally appear in enormous numbers, but they seldom live longer than a day to two. Occasionally, their dead bodies literally pile up along the shore, on bridges, or in the streets of nearby towns *(911)*.

Beyond the occasional nuisance created by the presence of piles of dead insects in areas frequented by humans, and the importance of the nymphs as fish food, which is substantial, mayflies are of no economic importance.

Order **Odonata**—*Dragonflies and Damselflies*

Dragonflies and damselflies are relatively large and often beautifully colored insects. The adults have two pairs of elongate, membranous, many-veined wings of about equal size. The head and the compound eyes are large, the antennae are very small and bristlelike, and the abdomen is long and slender. Dragonflies may be up to 75 mm long and they hold their wings in a horizontal position while at rest. Damselflies are usually somewhat smaller. Their wings are folded along the abodomen or are tilted up while at rest. Adults of both groups feed on various insects they capture while in flight. They are common and often abundant around slow streams and ponds. Dragonflies are particularly noticeable because of their large size and their rapid flight back and forth over the water.

Dragonfly and damselfly nymphs are all aquatic and feed on various small aquatic organisms. Prey is captured through the use of a modified labrum containing two movable clawlike lobes at the tip. This device is held folded under the head when not in use and is about one-third as long as the body when fully extended. The nymphs breathe by means of gills. In the dragonflies, gills are in the rectum; in damselflies, gills are three leaflike structures at the end of the abdomen. Mature nymphs crawl out of the water and transform to the adult stage, usually on rocks or vegetation.

Order **Plecoptera**—*Stoneflies*

Stoneflies are small to medium-size drab insects with soft flattened bodies. The wings are membranous and have numerous cross veins. The front pair is rather narrow and elongate; the hind pair is shorter but wider and is usually folded in pleats while at rest. The antennae are long, slender, tapering, and many-segmented. The cerci, when present, are usually long and many-jointed. The nymphs are flat-bodied and somewhat elongate. They have long antennae, long cerci, and branched gills on the thorax and about the base of the legs.

Stonefly adults occur near streams or along rocky shores of lakes. The nymphs are aquatic and are usually found under stones in rapids of streams. When they reach maturity, they leave the water and climb up on nearby objects to transform to the adult stage *(909)*.

Stoneflies may be a nuisance at times, especially when they appear in swarms in recreational areas. The nymphs are an important source of fish food.

Order Psocoptera—*Booklice and Psocids*

Booklice and psocids are small, soft-bodied, winged or wingless insects, usually less than 6 mm long. The more typical psocids have well-developed wings and bear a striking resemblance to aphids of the order Homoptera. The wings are held rooflike and almost vertically over the body while at rest. Booklice are either wingless or possess only vestigial wings, and are about 1 mm long.

Psocids are found under stones, on or under the bark and on the foliage of trees or shrubs. They are not injurious to trees but they may be a nuisance, especially when they occur in large numbers around residences or in recreational areas. They feed on fungi, lichens, and probably other vegetable matter.

Booklice occur most commonly in damp, dark rooms not generally used. They are occasionally found in old books, where they feed on the paste of the bindings. Sometimes they are abundant enough to cause serious damage.

Order Mallophaga—*Chewing Lice*

Chewing lice are all external parasites of birds and animals. The adults are small, usually flattened, and wingless. They feed on the feathers, hairs, or skin of their hosts. None is known to attack people. The order is divided into four families. Members of the family Trichodestidae attack various species of domestic animals, Gyropdidae feed on rodents, and the other two—Menoponidae and Philopteridae—feed on birds and poultry.

Order Anoplura—*Sucking Lice*

Sucking lice are small, wingless insects that live on the skin of various mammals and suck their blood. Their bodies are flattened, the mouth parts consist of piercing stylets, and there is a rostrum with many tiny hooks at the front of the head. The tarsus consists of a single large claw. This claw is opposed by a toothed projection on the tibia. The **body louse**, *Pediculus humanus humanus* L., and the **crab louse**, *Pthirus pubís* (L.), attack humans, and a number of other species attack various kinds of livestock and other animals. Published treatments of the order *(390, 410)* are available, as are discussions on control of species attacking people *(219, 370)*.

Order Thysanoptera—*Thrips*

Thrips are small slender-bodied insects, usually from 0.05 to 5.0 mm long. Adults are either wingless or have four long, narrow, fringed wings with few or no veins. The mouth parts are of the rasping, sucking type; the antennae are usually short and 6- to 10-segmented; the tarsi are 1- to 2-segmented, with one or two claws, and are bladderlike at the tip.

Thrips are frequently extremely abundant on flowers. Others occur on foliage, fruit, bark, fungi, and in debris. A number of species cause considerable damage to cultivated plants, but only a few have been reported injurious to trees *(38)*.

Liothrips umbripennis (Hood) is sometimes abundant enough on chestnut oak to cause the curling of leaves. The **slash pine flower thrips**, *Gnophothrips fuscus* (Morgan), was first reported as damaging to pine seedlings in nurseries in New York and Rhode Island and to jack pine on rocky slopes in Ontario. It is known as a serious seed orchard pest of slash pine in Florida and southern Georgia *(356, 547)*. It infests the female flower buds, flowers, and very young conelets, puncturing and

abrading scales and bracts. Heavy infestations result in obvious resinosus and death of flowers or conelets. Less intensive attacks kill scattered cone scales and result in gnarled, distorted cones in which seed loss is both direct from lost cone scales and indirect from poor seed release from the deformed cones. The **flower thrips**, *Frankliniella tritici* (Fitch), feeds on the flowers and flower buds of hawthorn, which sometimes prevents the buds from opening.

Order Neuroptera—*Dobsonflies, Lacewings, Antlions, and Allies*

This order contains a wide variety of terrestrial and aquatic insects. The adults have two pairs of large, membranous, leaflike wings that they hold rooflike over the abdomen while at rest. The antennae are generally long and many-segmented; the tarsi are five-segmented and there are no cerci. The larvae are practically all campodeiform and are usually armed with very large, curved mandibles.

Family Corydalidae
Dobsonflies

The best known species of this family is the **dobsonfly**, *Corydalus cornutus* (L.). The adult, especially the male, occasionally reaches a length of 100 mm, has two long curving pincers or mandibles, and has a wingspread of 100 to 125 mm. Females are similar in appearance except that the mandibles are smaller. The full-grown larva, commonly known as hellgrammite, is also large and formidable in appearance. Hellgrammites are found under stones in stream beds, especially where the water runs swiftest. After about 2½ years, they leave the water and construct cells in which to pupate under stones, logs, or other objects on or near the bank of the stream, usually during early summer. The hellgrammites are highly prized as fish bait; otherwise, members of the family are of little or no economic importance.

Family Chrysopidae
Green Lacewings

In both the adult and larval stages, members of the family Chrysopidae are all predacious on soft-bodied insects. They occur commonly in late summer and fall on the foliage of plants infested with these insects. Aphids and mealybugs appear to be preferred as hosts, but leafhoppers, thrips, mites, and certain species of scale insects are also attacked. The adults are green or yellowish green and have delicate, lacelike wings. Egg are usually laid at the ends of 3- to 4-mm-long gelatinous stalks firmly attached to the surfaces of leaves. The larvae are elongate, yellow or gray mottled with brown, and taper toward each end. Some species have the odd habit of covering their bodies with packets of trash woven together loosely with strands of silk. The winter is spent usually as full-grown larvae in silken cocoons in bark crevices or in such protected places as piles of leaves on the ground. There are one to several generations per year, depending on climate *(1111)*. The **goldeneye lacewing**, *Chrysopa oculata* Say, is an important predator of spruce gall adelgids in the Lake States.

Family Hemerobiidae
Brown Lacewings

Brown lacewing adults have brown or dark-colored bodies often marked with yellow; occasionally the abdomen is pale yellow. Otherwise, they resemble adult green lacewings very closely. All species are predacious on other insects, principally aphids, but also adelgids, mealybugs, whiteflies, mites, and occasionally diaspine scales. The larvae are similar in general appearance to the larvae of green

lacewings, but they do not carry packets of trash on the dorsum. Eggs are laid on the surface of leaves. Depending on the species, winter is spent in the larval, pupal, or adult stage. The number of generations per year varies from one to many, depending on species and climate.

Family Myrmeleontidae
Antlions

Antlion larvae, or doodlebugs, as they are also commonly called, live in tiny, conical pits or craters in the ground in dry, dusty, or sandy areas. The pits are usually about 37 to 50 mm wide and from 25 to 50 mm deep. The sides slant sharply from the rim to a point in the bottom. The adults have long slender bodies and two pairs of long, narrow, delicate, many-veined wings; larvae are broad, somewhat flat, taper toward each end, and have long, curved mandibles armed with strong spines and setae. The larva lies hidden under sand at the bottom of its pit and feeds on ants or other insects that fall into the pit.

Order Siphonaptera—*Fleas*

Fleas are small, wingless, hard-bodied, jumping insects. The body is strongly flattened laterally and is armed with numerous backward-projecting spines or bristles. The mouth parts are formed for sucking and the legs are long; there may be no eyes. Adults feed on the blood of birds, wild and domestic animals, and people. The larvae feed on organic matter, their own cast skins, and the feces of the adults. Many species are economic pests. About 75 species of animals and birds in the Eastern United States are attacked by more than 50 different species of fleas *(439)*.

Some of the more important eastern species are: the **human flea**, *Pulex irritans* (L.); the **cat flea**, *Ctenocephalides felis* (Bouché); the **dog flea**, *C. canis* (Curtis); and the **oriental rat flea**, *Xenopsylla cheopis* (Rothschild). The latter species is the principal vector of bubonic plague and may also transmit endemic typhus to humans.

Order Orthoptera—*Grasshoppers, Crickets, Mantids, and Allies*

The order Orthoptera contains some of our most familiar insects, and many of them are important household or agricultural crop pests. A few species are also injurious to trees.

Members of the order may be either winged or wingless. The winged forms have two pairs of wings, with the front pair generally long and narrow, many-veined, and leathery or parchmentlike. The hindwings are membranous, much broader, and are usually folded in fanlike pleats beneath the front wings while the insect is at rest. The body is elongate, and cerci are usually well developed. The females of many species have long ovipositors, often as long as the body.

Many publications have been issued on the Orthoptera *(7, 129, 453, 455, 542, 543, 544, 545, 889, 1016, 1226, 1317)*.

Family Mantidae
Mantids

Mantids are predacious and feed on a wide variety of other insects. They are large, elongate insects. The eyes are very large; the head is wider than it is long, and movable; and the prothorax is very long—sometimes nearly as long as the remainder of the body. The front coxae also are very long and the front femora and tibiae are armed with strong spines that fold together to form a pincer. To capture

their prey, they usually lie in wait for it, holding their front legs in an upright position. Once the prey comes within reach, the armed tibiae and femora shoot out with lightninglike speed to grasp it. Because of their habit of holding their front legs in an upright position, these insects are commonly called "praying mantis." Mantids lay their eggs in the fall in papier-mâché-like egg cases or ootheca, each of which contains 200 or more eggs; hatching occurs the following spring. There is one generation per year.

The **Carolina mantid**, *Stagmomantis carolina* (L.), is the most common species in the Southern States. It occurs from the Atlantic Coast to New Mexico and north to Nebraska, Pennsylvania, and Illinois. Adults are 75 to 100 mm long. The male is grayish brown with smoky-brown outer wings and often with a greenish-yellow body and legs. Females either are colored like the males or are greenish yellow with bright-green forewings. *S. floridensis* (Davis), a somewhat more slender and longer species, occurs in Florida.

The **Chinese mantid**, *Tenodera aridifolia sinensis* (Saussure), an introduced species, occurs in the Eastern States west to Ohio and south to South Carolina. The adults are elongate, robust, and about 100 mm long (fig. 11). Females are green or greenish yellow; males are the same color or wholly brown, or brown with green margins on the forewings. The **narrowwinged mantid**, *T. augustipennis* (Saussure), also an introduced species, is similar to but more slender and smaller than the Chinese mantid. It is widely distributed in the Eastern States.

Courtesy Conn. Agric. Exp. Stn.

Figure 11.—Adult and egg mass of the Chinese mantid, *Tenodera aridifolia sinensis*.

Two other eastern species are the **European mantid**, *Mantis religiosa* L., an introduced species (medium size and greenish yellow) and *Litaneutria minor* (Scudder). The latter is about 25 mm long, and occurs in the Great Plains *(509)*.

Family Phasmatidae
Walkingsticks

Eastern species of walkingsticks are long, slender, and subcylindrical. The head is free and nearly horizontal, the antennae are long, the eyes small, the abdomen is elongate, the legs very long and slender, and the wings are absent except for one species in Florida with rudimentary wings. Walkingsticks are slow-moving insects, and all are plant feeders. The eggs are hard-shelled and are often dropped or laid on the ground.

The **walkingstick**, *Diapheromera femorata* (Say), the only species of economic importance, occurs in southern Canada and throughout most of the Eastern United States west to the Great Plains and Texas. Its preferred hosts appear to be black oak, northern red oak, basswood, elm, black locust, and cherry, but it also feeds on white oak, quaking aspen, paper birch, ash, dogwood, and hickory.

Adults average 75 mm long and, while motionless, closely resemble the twigs of their hosts (fig. 12). The body color is variable. Some individuals are all brown or green; others are mottled or multicolored with dark or light shades of grays, greens, reds, or brown. Newly hatched nymphs are pale green, about 8 mm long, and look like miniature adults. The egg is very hard, oval, seedlike, shiny black or brown, and has a broad white or olive band on one edge. It is about 2 mm long.

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Figure 12.—Adult walkingstick, *Diapheromera femorata*.

Winter is spent in the egg stage and hatching occurs in May or early June. The nymphs feed at first on shrubs such as sweetfern, blueberry, strawberry, and serviceberry. Later, they feed on leaves of the same trees as the adults. Adults emerge in July or August and feed and lay eggs until the onset of cold weather. In heavily infested stands, the sound of falling eggs striking the ground is much like that produced by raindrops in a light shower. In the South most of the eggs hatch the following year; in the North most hatch the second spring following their deposition.

Severe outbreaks occur occasionally in the Lake States. They also occur less frequently south of a line drawn from Nebraska to Delaware. Trees may be defoliated twice in the same season during severe outbreaks. Branch mortality sometimes occurs in stands heavily defoliated three or four times; continued defoliation for several years may lead to considerable tree mortality *(493)*. Important natural control factors include the hymenopterous parasite, *Mesitiopterus kahlii* (Ashmead); various predators such as crows, robins, and other birds; and dry weather during the period of egg hatch *(1322)*.

Several other species of walkingsticks also occur in the Eastern United States. The **twostriped walkingstick**, *Anisomorpha buprestoides* (Stoll), is found in the Deep South, typically in oak stands growing on excessively drained, sandy soil in Florida. Eggs are laid in groups of 8 to 10, each in a small pit dug in the soil. *A. ferruginea* (Palisot de Beauvois) feeds on various trees and shrubs from southeastern Nebraska and Arkansas through the high country to Georgia and the Carolinas. *Diapheromera velii* Walsh and *D. blatchleyi* (Caudell) feed on grasses and tall shrubs. *D. velii* occurs in the Great Plains; *D. blatchleyi*, from the Great Plains to the Atlantic Coast. *Megaphasma denticrus* (Stål), the **giant walkingstick**, sometimes attains a length of 150 mm. Its habits are similar to those of *D. femorata*, but it is apparently never abundant enough to be injurious.

Family Acrididae
Grasshoppers

This family contains most of the well-known grasshoppers, some of which are frequently destructive to agricultural crops. Ordinarily, they are not very injurious to trees, but they may seriously damage them during outbreaks. Young trees in nurseries, shelterbelts, and plantations are particularly vulnerable, especially in the Great Plains, in the upper Mississippi Valley, and in the Lake States. The adults are distinguished by their short filiform antennae of 25 segments, short and inconspicuous ovipositors, auditory organs on the sides of the first abdominal segment, greatly enlarged hindlegs, narrow forewings, and broad, membranous, fanlike hindwings.

The majority of grasshoppers breed and live in the same general area throughout the year. Certain others may build up in such vast numbers that they are forced to leave their breeding grounds. At such times, they may travel considerable distances. All species have much the same life history. Nearly all lay their eggs in pods at depths of 25 to 75 mm in the soil in late summer or fall, usually in grain stubble, meadows, and along ditchbanks, fence rows, and roadsides. Hatching occurs in the South as early as February; in the Northern States, it usually occurs in May or June. Maturity is reached in 40 to 70 days, after which some adults live and feed until the onset of cold weather. The majority of species spend the winter in the egg stage, but a few overwinter as nymphs or adults, especially in the South.

The following are a few of the species that may be injurious in nurseries, plantations, and shelterbelts during epidemics. The **migratory grasshopper**, *Melanoplus sanguinipes* (F.)—the adult is about 20 mm long and reddish brown with a distinct patch of black on the neck or collar. The **differential grasshopper**, *M. differentialis* (Thomas)—the adult is 37 mm long. It is yellow with contrasting black markings; has clear, glossy hindwings; and usually bears yellow and black chevron-shaped bars on the sides of the thighs of the hindlegs. The **twostriped grasshopper**, *M. bivittatus* (Say)—the adult is about 30 mm long. It is slightly more robust than the differential grasshopper and is greenish yellow beneath, with two yellow stripes running the full length of the dorsum. The **redlegged grasshopper**, *M. femurrubrum* (De Geer)—the adult is about 18 mm long. It is reddish brown above, yellowish beneath, has colorless hindwings, and has red-tinged hindlegs. The **clearwinged grasshopper**, *Camnula pellucida* (Scudder)—the adult is about 12 mm long and yellow to brown. The forewings are blotched with large brown spots, and the hindwings are clear.

A few species of grasshoppers are more closely associated with trees than others. One, *Dendrotettix quercus* Packard, the **postoak locust**, is widely distributed from east-central Texas to the Lake States, Long Island, and southeastern Canada. Oaks

are its preferred hosts, but it has also been observed on pines in the Lake States. Several outbreaks have been recorded, some of which covered several square kilometers. During intervals between outbreaks, it is very scarce. Adults are present from June to September and lay their eggs in the soil in late summer. The nymphs climb the trees to feed. Other tree-infesting species are: *D. australis* (Morse)—apparently feeds exclusively on Virginia pine in the Southeastern States; *Melanoplus punctulatus* (Scudder)—has been observed defoliating young eastern white pines in plantations in Connecticut; *M. bruneri* (Scudder)—inhabits coniferous forests; and the **eastern lubber grasshopper**, *Romalea microptera* (Palisot de Beauvois)—feeds on shrubs in Florida and Alabama.

Family Tettigoniidae
Longhorn Grasshoppers and Katydids

Longhorn grasshoppers and katydids are mostly large with hairlike antennae, four-segmented tarsi, laterally flattened bladelike ovipositors, and auditory organs sometimes at the base of the front tibiae. The males "sing" by rubbing a sharp edge at the base of one front wing along a filelike ridge on the ventral side of the other front wing. The songs of different species differ in the character of the pulses, the pulse rate, and in the way the pulses are grouped.

Tree-inhabiting katydids are usually long-winged and green, matching the color of the foliage on which they feed. Eggs are laid end to end in overlapping rows on leaves or twigs, or are inserted into the edges of leaves. The winter is usually spent in the egg stage and hatching occurs in the spring. Some of the more common species, none of which is very injurious, are discussed below.

The **forktailed bush katydid**, *Scudderia furcata* Brunner von Wattenwyl, so-called because of the forked appendages at the top of the abdomen of the male, is widely distributed. It occurs on but is not restricted to trees. The related species, *S. curvicauda* (De Geer), lives commonly on oak.

The **broadwinged katydid**, *Microcentrum rhombifolium* (Saussure), is widely distributed in the East. Adults are 50 to 60 mm long and leaf green. The **angular-winged katydid**, *M. retinerve* (Burmeister), a smaller species, is more southerly in its distribution. Both species have long, narrow wings, and the vertex is narrowed anteriorly.

Pterophylla camellifolia (F.) is the katydid so commonly heard on summer evenings. The adult is large, green, and robust. The front wings are dark green, leaflike, very broad, concave within, and wholly enclose the abdomen. Infestations occur as small colonies in the dense foliage of trees. Eggs are laid in crevices of loose bark or within the soft stems of woody plants.

Other long-winged species include: *Hubbellia marginifera* (Walker), a large species with green front wings, sometimes spotted with brown, which occurs on pines in the Southeastern States, and *Conocephalus brevipennis* (Scudder), the **shortwinged meadow katydid**, which lays its eggs in willow in Canada.

Some members of the family have functional wings and live only on the ground. The most familiar species is the **Mormon cricket**, *Anabrus simplex* Haldeman. Although primarily western in distribution, it occasionally occurs in destructive numbers as far eastward as the Dakotas and Kansas. It feeds mostly on various trees and shrubs.

Family Gryllidae
Crickets

Crickets are medium-size insects, usually with long filiform antennae, three-segmented tarsi, spear-shaped ovipositors, and hindlegs fitted for jumping. The

wings of certain species are fully developed, and lie flat on the back and bend down abruptly at the sides of the body. In other species, wings are either abbreviated or absent. The winged forms possess auditory tympana on one or both sides of the fore tibia. The males also possess sound-producing organs near the base of the dorsal surface of the front wings.

There are several different kinds of crickets, the most familiar perhaps being the common field and house crickets of the genus *Gryllus (7)*. Tree crickets, however, are the only members of the family that are injurious to trees or shrubs.

Tree crickets are small, delicate, and pale colored. The tarsi are three-segmented, with the second segment small and compressed. The wings of the male are broad and lie flat over the abdomen, while those of the female are narrow and wrapped closely about the body. Tree crickets feed on other insects such as aphids, treehoppers, and scales; and also on the leaves, flowers, and bark of trees.

The **snowy tree cricket**, *Oecanthus fultoni* T. J. Walker, is a common species throughout the United States. Adults are pale green and about 14 mm long. The wings are transparent with a slight greenish tinge, and each of the first two antennal segments bears a black spot. Adults are found on various trees and shrubs, preferring those growing in the open. Eggs are laid singly in a row of punctures in the bark of twigs or small branches. *O. exclamationis* Davis is similar in appearance, habits, and range to *O. fultoni* except for a black club-shaped mark on the base of the first segment of the antenna. *O. pini* Beutenmüller occurs on pines and lays its eggs in regular rows on the bark. *O. latipennis* Riley occurs commonly on shrubs and low trees, especially on scrub oaks in dry open areas in the Eastern States.

Anurogryllus arboreus T. J. Walker, the **arboreal short-tailed cricket**, occurs mainly along the Atlantic Coast from New Jersey to Florida and westward to southeastern Texas. It has been observed damaging newly germinated slash pine seedlings in Louisiana, Texas, and Arkansas. It cuts off the seedlings, pulls them into its tunnels, and eats the tender foliage *(1238, 1259)*.

Family Gryllotalpidae
Mole Crickets

Gryllotalpa gryllotalpa (L.), the **European mole cricket**, an introduced species, occurs in a number of places along the East Coast. Adults are brownish yellow tinged with fuscous above and are pale, brownish yellow underneath. They are covered with velvety hairs and are up to 37 mm long. The forelegs terminate in four dactyls that are used for digging. This species feeds at night by tunneling in the upper 25 to 50 mm of soil. It cuts off the roots of seedlings, eats pits in underground roots and stems, cuts off stems above the ground, and eats seeds. It is occasionally injurious in nurseries.

The **changa**, *Scapteriscus vicinus* Scudder, a tropical species, occurs along the Coastal Plain of the Southeastern States. The adult is brown above, light brown below, and about 37 mm long. Its forelegs terminate in two dactyls. *S. abbreviatus* Scudder occurs in Georgia and Florida. Adults are brownish fuscous and blotched with yellow. The **southern mole cricket**, *S. acletus* Rehn & Hebard, occurs from Georgia to Texas. It is pinkish buff in color and somewhat more slender than *S. abbreviatus*. All members of this genus feed on earthworms, roots, and insects. They are occasionally injurious in nurseries.

Family Blattidae
Cockroaches

Several species of cockroaches may be found under the bark and in cavities in dead trees. They feed chiefly on animal and vegetable refuse and, as far as known,

are of no economic importance to forestry. The adults are distinguished by their depressed, oval bodies, their nearly horizontal heads, their slender, depressed legs of almost equal size, and the absence of long ovipositors in the females.

Order **Isoptera**—*Termites*

Termites constitute the order Isoptera. They are one of the oldest and most primitive groups of insects. Termites are social insects and live in colonies. In all species there is a definite caste system, with each of the adult castes performing an essential function in the life of the colony. Termites utilize cellulose, which they normally obtain from wood or other plant material, as their main energy source. Cellulose is normally indigestible to most animals; however termites have single-celled protozoa and bacteria within their digestive tracts that break cellulose into digestible units *(588)*. Many species of fungi are associated with termites in a beneficial manner. This association varies from little dependence on fungal activity in wood to a totally symbiotic relationship with fungi *(1053)*. The influence of fungi on the activity of termites is poorly understood but some species, such as *Gloeophyllum trabeum* (Pers. ex Fr.) Murr. *(Lenzites trabea* Pers. ex Fr.), are known to produce an attractant and a feeding stimulant *(829, 1121)*.

Only 38 species of termites are believed to be native to the continental United States. Of these, 14 are known to occur in the eastern half of the country, exclusive of western Texas *(1267)*. In addition to these native species, two introduced species, *Cryptotermes brevis* (Walker) and *Coptotermes formosanus* Shiraki, occur in the East. *C. brevis* may have been introduced into southern Florida. *C. formosanus* is believed to have been introduced into the Gulf Coast during World War II.

Termites are small, cylindrical, soft-bodied insects sometimes without eyes. The antennae are moniliform and, in the winged adults, the number of antennal segments varies from 12 to 25 or more. The median ocellus is absent. In certain species it is replaced by a more or less distinct opening of a gland known as the fontanelle. The wings are long and narrow and, when folded on the back, extend well beyond the end of the abdomen. In all North American species, the forewings and hindwings are similar in form and in the general features of their venation. The abdomen is broadly joined to the thorax.

Termites have very few effective natural enemies that attack individuals in the nest. For example, there are no known internal insect parasites, and predacious enemies are largely limited to ants, lizards, and birds. During and after the swarming period the winged adults of many species are eaten by all sorts of animals, particularly other arthropods (scorpions, solpugids, spiders, centipedes, dragonflies, cockroaches, mantids, crickets, beetles, flies, and wasps) and vertebrates (fish, frogs, toads, lizards, snakes, birds, and mammals, including humans) *(741)*. These predators may have some adverse effect on the establishment of new colonies but probably have no effect at all on the parent colony. As yet, there are no studies on the rate of predation and its possible significance in controlling the populations of a single species of termite *(941)*. Fungi, nematodes, and bacteria usually kill a small percentage of the individuals in a colony. Occasionally molds cause much heavier losses.

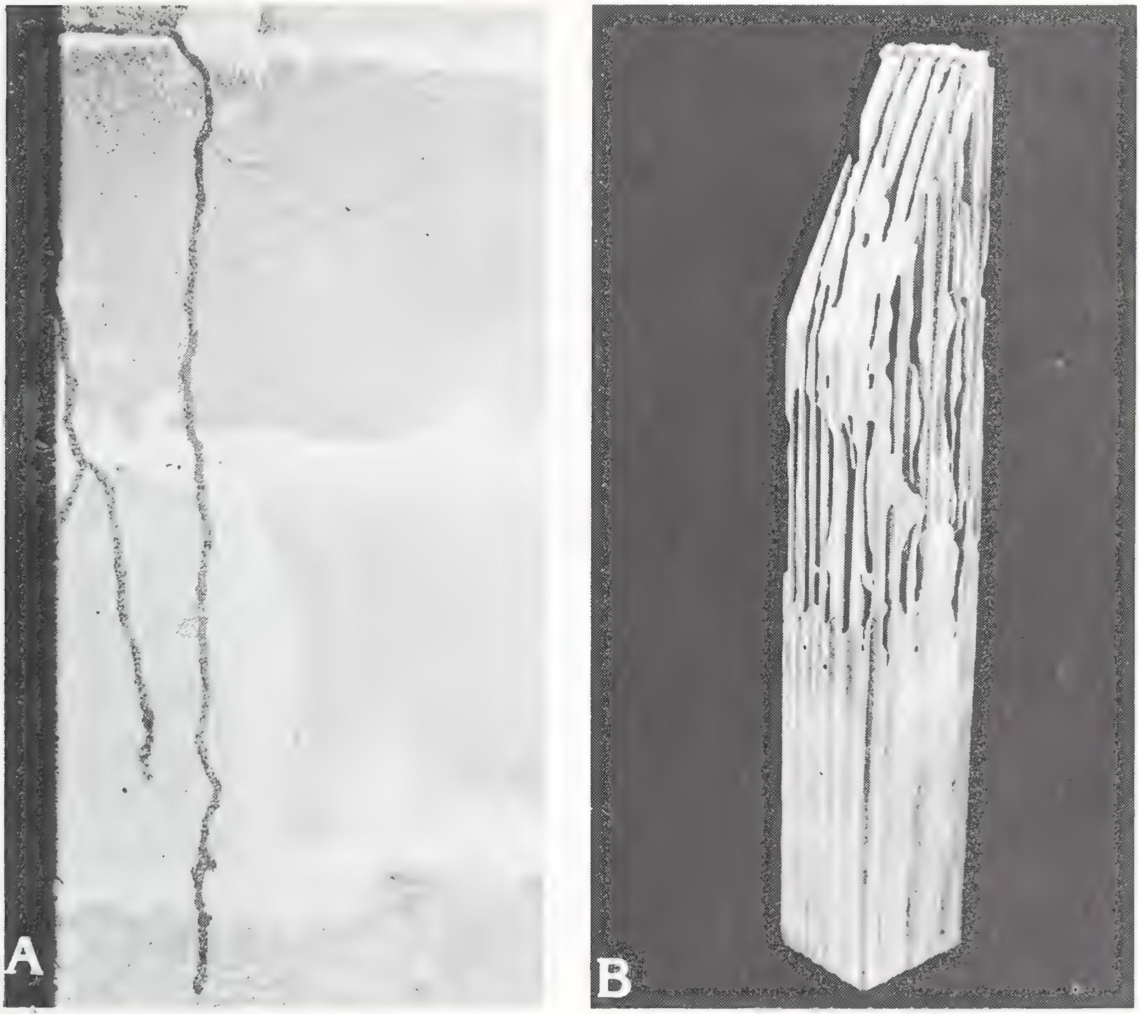
In many parts of the Eastern United States, particularly the South, termites are almost universally present in stumps, logs, and other woody materials in contact with the ground. Termites are largely beneficial in forested areas because of their value in the decomposition of dead wood and its reincorporation into the soil.

However, when termites infest wooden structures and other useful wood products, they are often extremely destructive. The extent of the monetary losses they cause is not known. Estimates vary, however, from $100 to more than $750 million per year in the United States for damage, repairs, and preventive and remedial control *(645, 757, 832)*.

For further information on termites, the reader is referred to the following studies: *365, 366, 536, 566, 617, 645, 686, 695, 696, 720, 1266, 1316.*

Family Rhinotermitidae
Subterranean Termites

The subterranean termites of the Eastern United States all belong to the family Rhinotermitidae. Because these termites all require a constant supply of moisture, their colonies are found either entirely or partly in the ground. They may, however, feed in wood located some distance from the ground, but they always maintain connection with the ground unless a continuous supply of water is otherwise available. In order to attack wood located away from the ground where a supply of water is not available, they construct covered passageways, commonly called shelter tubes (fig. 13A).



F-531242

Figure 13.—Subterranean termite: A, shelter tube on foundation wall; B, damage to a pine stake.

Regardless of the extent of damage they cause to the interior of wood (fig. 13B), these termites always leave a covering shell intact. Because of this shell, there usually is no external evidence of infestation, even though the interior of the wood may be destroyed. The first indication of infestation may be the swarming of

winged adults, the presence of shelter tubes over foundation walls, or the sudden collapse of the surface of infested wood.

The principal food of subterranean termites is cellulose, which they obtain from wood and other plant tissues. As a result, these termites are not only destructive to the woodwork of buildings, utility poles, fence posts, and other wood products, but also to paper, fiberboard, and various types of fabrics derived from cotton and other plants. Shrubs, nursery stock, ornamental plants, and many kinds of shade trees are damaged occasionally. Trees killed by other insects, fire, or disease, particularly in the South, are attacked and the timber rendered unmerchantable unless it is utilized shortly after being killed.

In attacking wood, subterranean termites usually feed on the soft springwood only. As a result, their galleries run with the grain. These galleries are characteristically stained on the inside with grayish specks of excrement and earth but are free of pellets like those found in the galleries of nonsubterranean termites.

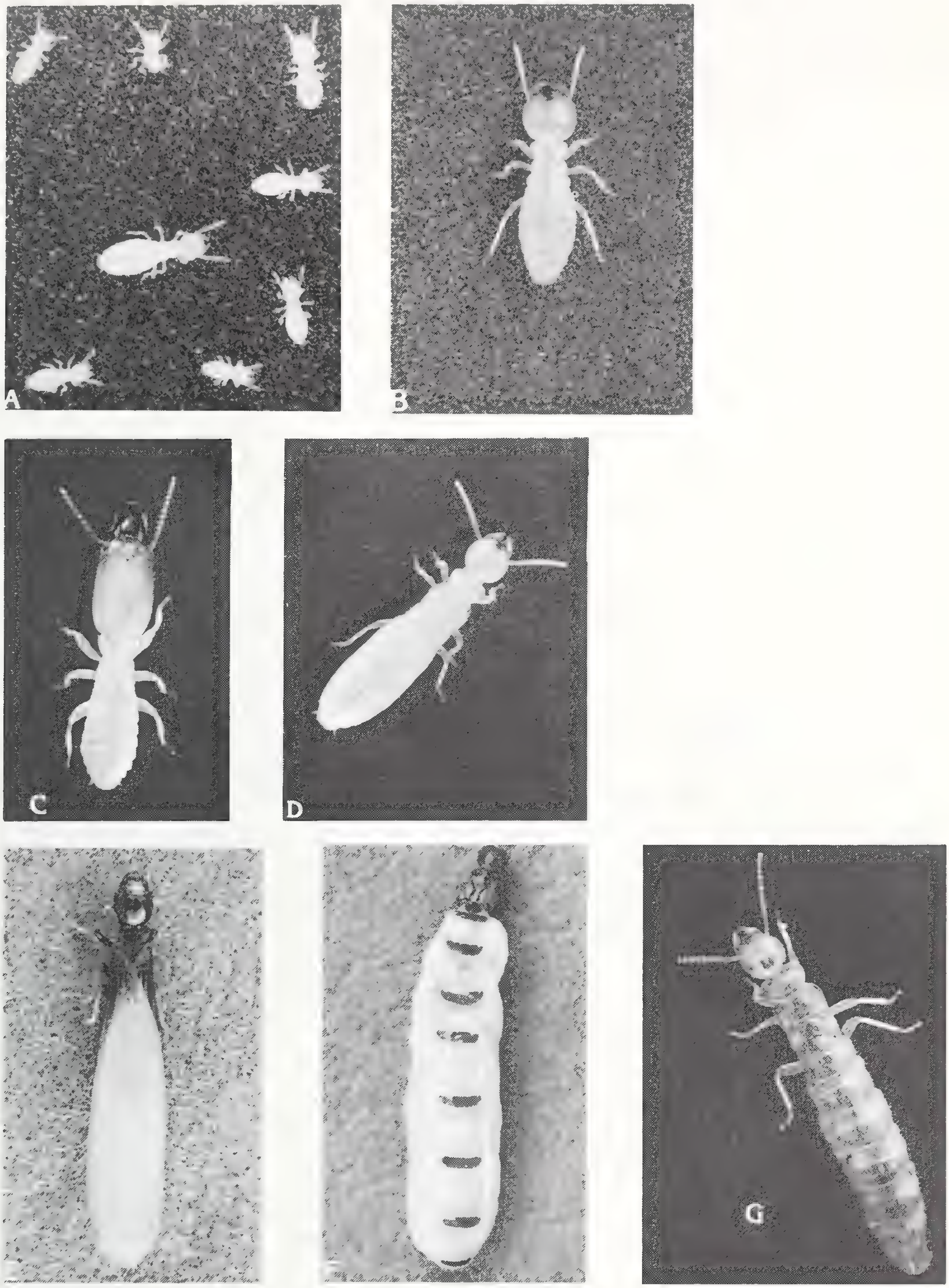
Subterranean termites occur throughout most of the United States and in southern Canada. They are common in most of the eastern half of the United States and along the Pacific Coast. It is considered likely that the native species have occupied their present ranges for millions of years; however, there seems to be an increase in their destructiveness northward. This increase has probably resulted from the general adoption of central heating plants in structures, from changes in building practices, the wider use of termite-susceptible wood in construction, and from the tremendous expansion of suburban homes into forested areas.

The **eastern subterranean termite**, *Reticulitermes flavipes* (Kollar), is the predominant species in the Eastern United States. It occurs from the East Coast to the Great Plains and from the Gulf of Mexico north to Ontario. In general, *R. flavipes* occupies regions of high humidity. Dead wood in forested areas is commonly infested with this species. It will attack wood from most of the species of trees in this part of the country. Infestations also occur in the woodwork of buildings, in cellulose materials in storage, and in poles and posts.

Every mature colony of the eastern subterranean termite contains some or all of seven castes during the year: larvae or immatures, nymphs, soldiers, workers (a "true" worker caste is not believed to exist in *Reticulitermes)*, alates or winged reproductives, and primary and supplementary (or replacement) reproductives. Larvae hatch from the eggs and are precursors of all the other castes (fig. 14A). Workers (fig. 14B) are soft-bodied, grayish white, and slightly less than 6 mm long. They are the individuals responsible for the maintenance of the colony and the gathering of food. Soldiers (fig. 14C) are similar to the workers except for their much larger, long heads, their larger and more formidable mandibles, and their slightly greater length. Soldiers cannot feed themselves but contribute to colony labor by defending it. Nymphs (fig. 14D) develop from larvae and eventually molt into reproductives (fig. 14E). These reproductives are soft-bodied and brown to black, have two pairs of long, whitish opaque wings of equal size, and are 10 to 12 mm long. The winged reproductives fly from their colony to form new colonies.

Colonizing flights occur during the day, most frequently after the first warm days of spring, often following a warm rain in April or May. They may also occur during the remainder of the warm season and sometimes even in the fall, especially in the South. In heated buildings, flights occasionally occur during the winter. The individuals in these flights are attracted by strong light. When they emerge within buildings, they gather about windows and doors. Here, they soon shed their wings, which may be found in large numbers even after the termites have disappeared.

Soon after shedding their wings, males and females pair off and search for a place to form a new nest. The great majority of them are usually unsuccessful, but some survive and manage to hollow out small cells in the ground near wood. They enter the cell, seal the opening, and eventually mate.



A,B,E,F: F-531243
D: F-531902
C,G: Courtesy South. For. Exp. Stn., Gulfport, Miss.

Figure 14.—Eastern subterranean termite, *Reticulitermes flavipes*: A, larvae or immatures; B, worker; C, soldier; D, nymph; E, winged primary reproductive; F, physiogastric female primary reproductive; G, female supplementary reproductive.

A few days after mating, the female lays from 6 to 12 eggs. Hatching occurs in about 50 to 60 days, and the young larvae grow to maturity in less than 1 year. Later, both soldiers and reproductive nymphs appear in the colony and reach maturity within 1 and 2 years, respectively. Mating continues at irregular intervals, and the colony continues to increase in size. The original pair of reproductives lives together for life, sometimes for many years. The female increases greatly in size (fig. 14F) and produces literally thousands of eggs in her lifetime. In well-established colonies, there may be hundreds of thousands of individuals. In very large colonies, supplementary reproductives (fig. 14G) will develop in a colony to produce eggs if the primary reproductives die. These large colonies may be so widely spread out that it is difficult or impossible to estimate their size or to locate their main parts.

Reticulitermes tibialis Banks is the most widely distributed species of *Reticulitermes* in North America. It is largely confined to the arid areas of the western half of the United States but also occurs eastward in the North Central States as far as the Chicago area. To the east, *R. tibialis* overlaps a portion of the ranges of *R. flavipes, R. hageni* Banks, and *R. virginicus* (Banks). Along the southern shores of Lake Michigan, *R. tibialis* coexists with *R. arenincola* Goellner among sand dunes, where it infests small pieces of wood partly buried in the sand. Farther to the southwest, in Kansas and Texas, it occurs in heavily sodded prairies and in hard-packed and often alkali soil.

While *R. tibialis* is fully capable of damaging buildings, it is not as economically important as *R. flavipes* because of the thinly populated regions in which it occurs. Flights of this species occur over a large part of the year during the fall, winter, or spring, depending on the locality. Winged adults, in general, are almost entirely shiny black and about 10 mm long. The tibiae are also blackened and the pronotum is broad.

Reticulitermes virginicus occurs in the southeastern and central portions of the United States. Its range coincides closely with that of *R. hageni* in the east, although it does not appear to extend as far to the west. It is often mistaken for *R. flavipes* but is smaller. Throughout its range, *R. virginicus* overlaps the region occupied by *R. flavipes*, but it does not extend into the northern regions occupied by this latter species. In general, the line of northward extension of *R. virginicus* coincides with the regions where the average annual minimum temperature does not fall below $-23°$ C. Westward, this species extends through southern Illinois and Missouri, south to the coast of the Gulf of Mexico, as far west as Houston, Tex., and eastward to the southern tip of Florida *(1267)*.

Reticulitermes hageni is a small yellow-brown species and is the most distinctive of the *Reticulitermes*. It occupies about the same territory as *R. virginicus*. These two species are reported to occur more commonly in drier forested areas than does *R. flavipes*.

Reticulitermes arenincola was described from collections from the sand dunes along the southern shore of Lake Michigan in Indiana and Michigan. Little has been detailed regarding the field biology of this species. It inhabits sandy areas, and its flights occur toward the end of May.

Flights of *R. virginicus* tend to occur later in the spring than those of *R. flavipes*, although some overlap occurs between these two species. Flights of *R. hageni* tend to occur later than those of *R. virginicus*, although, again, there is some overlap between species. Flights of *R. virginicus* in the southern portion of its range occur

earlier than flights in the northern portion, even within buildings. This is not the case with in-building flights of *R. flavipes (1267)*.

All species of *Reticulitermes* that occur in the Eastern United States are economically important with the possible exception of *R. arenincola*. The taxonomy of the genus is not well established. Although there can be little doubt that there are physiological, behavioral, and ecological differences among species, there is no evidence to suggest that control methods for one should be different from control methods for another. One should be certain of the genus but, except as a matter of interest, the particular species cannot now be considered critical from the standpoint of control.

The **Formosan subterranean termite**, *Coptotermes formosanus* Shiraki, is an introduced species. Active colonies were first recorded in North America in a shipyard warehouse in Houston, Tex., in 1965. Since then additional colonies have been discovered in Houston and Galveston, Tex.; Charleston, S.C.; and New Orleans and Lake Charles, La. The species was described from individuals collected in Formosa in 1909. Since then it has been reported from Ceylon, China, Guam, Hawaii, Japan, and South Africa. Incipient colonies generally start in or near the soil where moisture and damp wood are available. Nests are normally built in soil near the base of tree stumps, utility poles, or other underground food sources, but they may be found almost anywhere if conditions are favorable. Colonies have been observed on boats, ships, barges, dredges, water tanks, piers, floating drydocks, in living and dead trees, and in buildings.

Workers are grayish white overall. The head is pale yellow, with a white mark in the center and a dark-brownish spot on each side of the clypeus. The pronotum is nearly twice as broad as it is long, and the legs are slender and hairy. Soldiers (fig. 15) have oval heads and slender bodies. The pronotum is short, elliptical, and notched at the middle of the frontal margin. A small, short tubelike process extends from the frontal gland and exudes a milky, acidulous secretion. The abdomen is slender, entirely pubescent, and bears a pair of three-segmented caudal appendages (cerci). Alates have large, hyaline wings, 10.6 mm long, about three times as long as the abdomen, and about three times as long as they are broad. The head is hexagonal and brown; the frons is irregularly concave at the center where a globular projection occurs; the pronotum is semicircular and as broad as the head; the legs are short, heavy, and yellowish brown; and the abdomen is short, elliptical, and yellowish brown. The bodies are marked with minute spots, and the wings are 12 to 14 mm long.

Nests of Formosan subterranean termites are constructed of a friable material called carton. It consists of a mixture of masticated wood, saliva, and excrement. A nest may be several cubic feet in volume. Tunnels radiate from nests constructed in the soil. They can be found at depths of 3 m in the earth and extend horizontally up to 60 m *(665)*. Their walls are lined with essentially the same materials used in constructing the nest and are nearly impervious to water. Primary queens can lay up to 1,000 eggs per day, and a single colony may contain many hundreds of thousands of individuals. Winged reproductives swarm during May and June. They are poor fliers, and the majority drop to the ground within 90 m of the nests unless carried farther by the wind. First evidence of a colony's presence may be the appearance of these winged adults at swarming time.

Large colonies can cause severe damage in a short time (fig. 16A). In Hawaii, walls of new buildings have been hollowed out in 3 months' time. Living trees are also hollowed out (fig. 16B) and weakened. Known susceptible trees in the South

are the Chinese elm, several species of oak, hackberry, and velvet ash. Dead trees are highly susceptible. Extensive damage all the way to the top of 20-m-tall baldcypress snags has been observed in Louisiana *(77)*.

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Figure 15.—Soldier of the Formosan subterranean termite, *Coptotermes formosanus*.

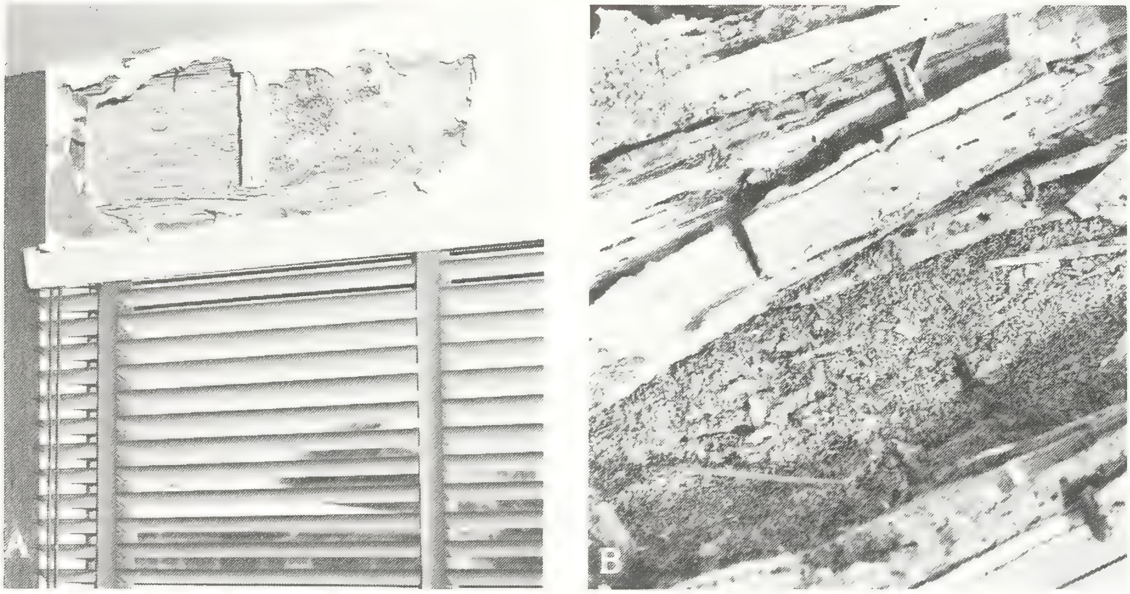

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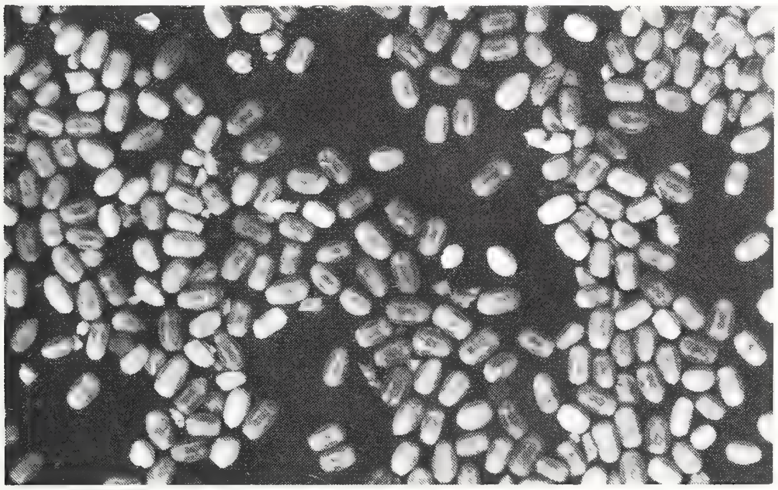
Figure 16.—Formosan subterranean termite colony and damage: A, carton nest and damaged wood above a window inside a building; B, colony of workers in a cypress log.

Families Kalotermitidae and Rhinotermitidae Nonsubterranean Termites

Many species of nonsubterranean termites occur in the Eastern States. They are found throughout Florida, also in a narrow strip along the Atlantic Coast as far north as southeastern Virginia, and westward along the Gulf Coast to Mexico. Infestations are found in structural timber and other woodwork in buildings, furniture, utility poles, wooden derricks, piles of lumber, wood pulp or fiber

insulation boards, in other products containing cellulose, and in trees and other plants. Because of their ability to live in wood that is frequently moved, nonsubterranean termites are often found in regions far removed from their normal range, including Canada. None of these termites is able to establish permanent infestations if transported out of its normal range *(366, 1124)*.

Nonsubterranean termites usually are less injurious than subterranean species in the Eastern United States. However, many years ago, large buildings in the South were seriously damaged *(1122)*. Nonsubterranean termites fly directly to and enter untreated and unpainted wood at swarming time. They cut across the grain of the wood and excavate broad pockets or chambers connected by tunnels of small diameter. They feed on both the soft springwood and the harder summerwood. Their cavities contain compressed fecal pellets which often have six darkened grooves along their length (fig. 17). Some of these pellets are pushed to the exterior through small holes and are found in piles on the floors of infested buildings.



F-519928

Figure 17.—Fecal pellets of nonsubterranean termites.

Nonsubterranean termites have a caste system similar to that of *Reticulitermes*. However, few of the species, except *Prorhinotermes*, contain individuals that could be considered workers. Most of the termites present are larvae or nymphs, and most of the work of the colony is performed by the nymphs.

Winged adults usually swarm during the early evening or morning hours in late winter or spring. Unless carried by the wind, they fly for only short distances in search of places to start a new colony. Once they have succeeded, they shed their wings and bore directly into the wood. Then they plug the opening, and seal themselves in. Colonies grow very slowly, are seldom confined to a single chamber, and rarely contain more than a few thousand individuals. Piles of pellets on the floor may be the first evidence of infestations. Other telltale evidence consists of pitted and roughened surfaces of infested floors, doorframes, and other wood.

Cryptotermes brevis (Walker) (Family Kalotermitidae) occurs commonly in southern Florida and is fairly widespread (although not abundant) on the coast of the Gulf of Mexico as far west as Brownsville, Tex. Isolated infestations have also been found elsewhere, including Tennessee, Maryland, Ohio, and New York. In most cases these infestations have been directly linked to transport of furniture from the Southern United States, particularly Florida and Hawaii, and from the Orient. Quarantine officials commonly intercept this species in cargo entering the United States from tropical and semitropical areas of the world. *C. brevis* has not been

recorded in any natural habitat, but only in fabricated structures. It can attack buildings but is particularly noted for severe damage to floors, woodwork, and especially furniture.

Cryptotermes cavifrons Banks (Family Kalotermitidae) occurs in southern Florida in dead trees, logs, stumps, and branches. Unlike *C. brevis*, which seems to be confined to structures, *C. cavifrons* has rarely been associated with buildings or furniture. The usual habitat of this species is in dry, sound, hardwoods in the hammock areas in southern Florida *(1267)*.

Incisitermes snyderi (Light) (Family Kalotermitidae) is the common dry-wood termite of the Southeastern United States. It occurs from South Carolina to Florida and west to Brownsville, Tex., mainly along the coast, but as far north as Alexandria, La. Infestations occur in the woodwork of buildings, in untreated utility poles, and in dead trees, logs, and branches. It does not appear to have the wide ecological range of *I. minor* (Hagen) (Family Kalotermitidae), which occurs in western North America. Collection records suggest that this species is not as subject to transport and survival in new localities as are *I. minor* and *C. brevis*. It does not seem to be as great an economic problem, generally, as is *I. minor* on the West Coast.

Incisitermes schwarzi (Banks) (Family Kalotermitidae) is the common dry-wood termite in southern Florida, occurring also in the northern portion of the State. It is common in coastal and everglade hammocks, and has a fairly high moisture requirement. Infestations are found in the woodwork of buildings and in dead trees, logs, and stumps. Two rather distinctive forms of soldiers ("longheaded" and "shortheaded") occur in colonies of this species *(1267)*.

Incisitermes milleri (Emerson) (Family Kalotermitidae) is a very small termite that occurs on the southern Florida Keys. It is encountered in very dry wood *(1267)*.

Kalotermes approximatus Snyder (Family Kalotermitidae) occurs primarily in northern and central Florida. Other scattered collection records of this species suggest it may have a much wider range than generally believed and perhaps is not frequently collected because it does not frequent houses as much as some of the other dry-wood termites. It has been reported to occur in dead wood of oak, sweetgum, and magnolia in Florida. Apparently it occurs in dead wood and in dead areas of living trees. There are few flight records for this species. It is reportedly a diurnal flier, as its deep pigmentation suggests, which is not the normal case for dry-wood termites *(1267)*.

Neotermes castaneus (Burmeister) (Family Kalotermitidae) is a very large species that occurs in the southern portion of Florida and on the eastern Keys. It has not been found in woodwork in buildings. Infestations have been limited to dead wood of trees, logs, stumps, and branches, and to living citrus trees. *N. jouteli* (Banks) (Family Kalotermitidae) occurs in the coastal areas of southern Florida, including the Keys. It is occasionally found in moist foundation timbers of buildings, but in nature it lives in dead trees and in logs and branches lying on the ground. Both of these species have a fairly high moisture requirement. Their workings are often situated in fairly damp wood or in dead wood adjacent to the living wood in living trees.

Calcaritermes nearcticus (Snyder) (Family Kalotermitidae) is also known only from Florida. It is similar to *Cryptotermes*; however, it occurs in damper wood and lines some of its galleries with brownish material.

Prorhinotermes simplex (Hagen) (Family Rhinotermitidae) is found only in Florida in the United States. It has a very limited distribution on some of the southeastern Keys and on the mainland occurs only in Dade County. It occurs in mangrove swamps on the coast and in pine forest areas in the lower Everglades. It is fairly common in the Miami area but is not found north of Fort Lauderdale. It has not been collected more than 10 km from the coast. This coastal distribution is typical of this genus throughout the world *(1267)*.

Order Hemiptera—*True Bugs*

The order Hemiptera consists of a large and widely distributed group of insects. The majority of species are terrestrial in habit, but several are aquatic. Many of the terrestrial forms are phytophagous and feed on a wide variety of trees and smaller plants. Trees, fortunately, are seriously damaged by only a few species. The order also contains a large number of predatory species, many of which feed on other insects and their eggs. A number of others feed on blood of humans and other animals and are decidedly obnoxious or harmful, especially those that transmit disease-causing organisms.

The majority of the Hemiptera have the basal portion of the forewing thickened and leathery, and only the apical portion is membranous. It is from this "half-wing" appearance that the order gets its name. The hindwings are entirely membranous and usually slightly shorter than the forewings. Both pairs of wings lie flat over the abdomen with the membranous distal portion of the front ones overlapping. The mouth parts consist of a bundle of stylets inside a segmented sheath. This slender beak arises from the front part of the head and usually extends backward along the underside of the body, sometimes to the base of the hind pair of legs. Feeding is accomplished by inserting the stylets into the tissues of the plant or animal host and sucking up the juices or blood. The beak sheath folds back beneath the insect as the stylets pierce deeper into the tissues. The antennae are fairly long and consist of four or five segments. Many species have scent glands which give off offensive odors when the insect is disturbed. Comprehensive studies have been made of the Hemiptera of eastern North America *(130, 157)*.

Family Pentatomidae
Stink Bugs

Pentatomids are commonly called "stink bugs" because of the disagreeable odor they emit when disturbed. The adult is usually a broad, short, slightly convex insect. The antennae are five-segmented, and the head and thorax sometimes form a triangle. Many species are brightly colored or conspicuously marked. Green ones may be difficult to detect on leaves. Dark-gray ones are also difficult to see when they rest on the bark of limbs and trunks of trees. Most species are plant feeders, but some feed on other insects, and some feed on both.

The **shieldbacked pine seed bug**, *Tetyra bipunctata* (Herrich-Schäffer), occurs on loblolly, slash, shortleaf, longleaf, Virginia, eastern white, red, jack, and sand pines and is an important pest in southern pine seed orchards *(286, 360)*. The adults and nymphs are oval and have a humpbacked appearance. The adults are about 15 mm in length. Their color varies from gray-brown in the early stages to a dark reddish-brown with black markings as adults. Their shape and color provide concealment while they feed on nearly mature cones. When motionless, they are not readily noticeable. The eggs are small, green spheres 1.5 mm in diameter. About a dozen eggs are laid in two alternate rows along a single needle or in a group

on a cone scale. Nymphs of all stages are gregarious. There is only one generation each year. Nymphs and adults have piercing-sucking mouth parts that they insert into cones to penetrate the seeds. Nymphs in the third stage and older, as well as adults, destroy seeds in developing cones. Most of the seed damage occurs in late summer and fall and can be detected on radiographs *(287)*. In seed orchards, losses are reflected by poor seed viability and low yields of sound seeds per cone.

Other plant-feeding species and their hosts include: *Brochymena quadripustulata* (F.), the **fourhumped stink bug**—feeds through the bark of limbs and trunks of elm, oak, and willow. Brownish, hairlike lines running across the grain in the cambial region are evidence of its attack. Adults frequently overwinter in houses. *B. carolinensis* (F.)—feeds through the bark of slash pine and longleaf pine. *Elasmuche lateralis* (Say)—feeds on the leaves and catkins of yellow birch. *Pitedia uhleri* (Stål)—feeds on the larger branches and trunks of eastern white pine in the Lake States.

Predacious species include the **spined soldier bug**, *Podisus maculiventris* (Say), which has been recorded feeding on more than 30 species of destructive insects, many of which are forest pests. The adult is dull yellow above, with numerous dark-brown punctures, and is about 12 mm long. Also, *Stiretus anchorago* (F.) feeds on the larvae of many species, including the gypsy moth and tent caterpillars. Adults are shiny, dark metallic, and 8 to 11 mm long.

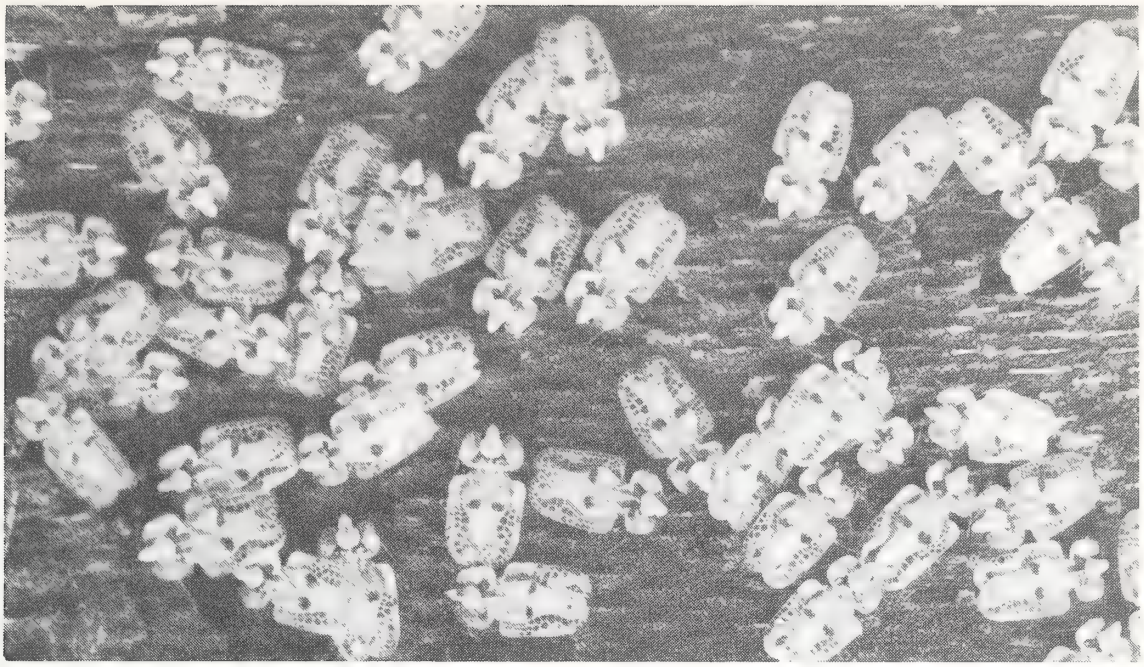
Family Tingidae
Lace Bugs

Lace bugs, so-called because of their broad, lacelike forewings, are usually whitish and 5 to 6 mm long. They are flat, oval or rectangular, and the head is often hidden beneath a large hood on the front of a greatly modified pronotum, which projects beyond the sides of the body. The abdomen is completely beneath the forewings, which are frequently transparent. The nymphs are black and often covered with long spines.

Many species of lace bugs live and feed on the undersurfaces of leaves. A given species usually occurs either on a single host or on closely related ones. The upper surfaces of infested leaves become whitened or brownish, or dead in appearance. The undersurfaces are speckled with eggs, excrement, and cast skins of the developing nymphs. The leaves of heavily infested trees may turn entirely brown and fall off. The winter is spent as adults under bark scales or other cover on the host tree, or as eggs cemented to the undersurfaces of leaves or embedded in leaf tissues. Most species have two generations a year.

The **sycamore lace bug**, *Corythucha ciliata* (Say), occurs throughout the Eastern United States *(1235)* and in southern Canada. Its preferred host is sycamore, but it also feeds occasionally on ash, hickory, and mulberry. The adult (fig. 18) is white and about 3 mm long. Overwintering adults emerge early in the spring and deposit their eggs along the ventral surface of the midrib of a leaf. Hatching occurs in 2 to 3 weeks, and the nymphs feed for 5 or 6 weeks. There are two generations per year in the North, probably more in the South. Light feeding causes a stippling on foliage. Heavily infested leaves of sycamore turn white and drop prematurely. During dry weather this may result in severe injury.

The **oak lace bug**, *C. arcuata* (Say), feeds on white, bur, and chestnut oaks from Alabama and the Carolinas to southern Canada. Its life history and control have been described *(233)*. The winter is spent in either the egg or adult stage. Infested leaves appear grayish white. Heavily infested trees may be defoliated, especially during dry weather. Bur oak in shelterbelt plantings is especially susceptible.



Courtesy Conn. Agric. Exp. Stn.

Figure 18.—Adults of the sycamore lace bug, *Corythucha ciliata*.

The **elm lace bug**, *C. ulmi* Osborn & Drake, feeds on American elm in many Eastern States and southern Canada, and on Siberian elm on the northern Great Plains. It is capable of defoliating its host.

Heavy infestations of *C. mollicula* Osborn & Drake may seriously injure willow, its only known host, throughout the Eastern States. Heavy infestations of the **hackberry lace bug**, *C. celtidis* Osborn & Drake, often occur on hackberry in the Midwest. The species has also been reported from Florida. *C. pallipes* Parshley, the **birch lace bug**, is often abundant on young yellow birch. Other hosts include paper birch, beech, eastern hophornbeam, willow, mountain-ash, and maple. *C. pergandei* Heidemann feeds principally on alder and occasionally on hazel, elm, and birch. *C. pruni* Osborn & Drake feeds on pin cherry; *C. juglandis* (Fitch), the **walnut lace bug**, on black walnut, butternut, and basswood; *C. elegans* Drake on willow, balsam poplar, quaking aspen, and bigtooth aspen; *C. aesculi* Osborn & Drake on buckeye; *C. associata* Osborn & Drake on pin cherry; *C. bellula* Gibson on hawthorn; and the **hawthorn lace bug**, *C. cydoniae* (Fitch), on hawthorn and pyracantha.

The **basswood lace bug**, *Gargaphia tiliae* (Walsh), often occurs in large numbers on the undersides of the leaves of basswood. Adults overwinter either under leaves on the ground or in bark crevices. There are two generations per year.

Family Reduviidae
Assassin Bugs

Most species of assassin bugs are predacious on other insects, but some are blood-sucking and frequently bite people. Many species are capable of inflicting painful bites and will do so if carelessly handled. Most species are found on various parts of plants, but a few are found on the ground or under objects on or near the ground. Adults are varicolored, usually black, brownish, green, or orange. They range greatly in size, some being more than 25 mm long. The head is long, narrow, and cylindrical with the part behind the eyes necklike. The head bears a stout, rigid, three-jointed beak that usually curves downward in the form of a semiloop, with the tip resting in a groove in front of and between the front legs. The margins of the abdomen are often exposed beyond the edges of the wings.

The **wheel bug**, *Arilus cristatus* (L.), is an important predator of various forest insects. As a young nymph it feeds on aphids, and later it attacks lepidopterous larvae such as the fall webworm and other insects such as the locust borer. The adult is a large, striking insect, with coglike teeth projecting from a median, longitudinal ridge on the thorax. The female is much larger than the male and may reach a length of 30 mm.

Other species attacking forest insects include: *Sinea spinipes* (Herrich-Schäffer), which feeds on the fall webworm in the South; *Acholla multispinosa* (De Geer), an enemy of the pine webworm; *Zelus exsanguis* Stål, an enemy of the gypsy moth; and *Melanolestes picipes* (Herrich-Schäffer), an enemy of May beetles and their larvae. The biologies of various species of this family have been reported *(1013)*.

Family Nabidae
Damsel Bugs

Damsel bugs appear to be entirely predatory on soft-bodied plant-feeding insects. Adults are usually pale brown to straw colored and about 8 mm long. The forelegs are quite slender and fitted for grasping, having the tibiae armed with minute spines and the femora enlarged. *Nabis sordidus* Reuter is a common species in eastern forests. It often occurs in large numbers on rank undergrowth.

Family Anthocoridae
Flower Bugs

The majority, if not all, of the members of this family of small bugs are predacious on other insects. The adults may be found on flowers, under loose bark, in leaf litter, or in decaying fungi. *Anthocoris musculus* (Say) feeds on soft-bodied, leaf-feeding insects, principally lace bugs, on deciduous trees in the Northern States. *Elatophilus inimica* (Drake & Harris) feeds on the red pine scale in Connecticut; it has also been found on pines infested with *Matsucoccus gallicolus* Morrison in Massachusetts. The majority of flower bugs are black with white markings and are only about 3 to 5 mm long. *Orius insidiosus* (Say) is a common predator of insect eggs.

Family Miridae
Plant Bugs

This is the largest family in the order Hemiptera, with about 1,600 species occurring in the United States and Canada alone *(675)*. The majority of species appear to be phytophagous. Many others are predacious and feed on a wide variety of young or soft-bodied insects. The adults are 2 to 9 mm long. The antennae and beak are each four-segmented, with the second segment of the beak longer than the head. The tarsi are usually three-segmented. The hemelytra, when fully developed, are separated into a clavus, corium, cuneus, and membrane. In some species, the hemelytra are abbreviated and the membrane is either absent or reduced to a narrow band.

The oaks, ashes, hickories, and birches serve as hosts for many species. *Tropidosteptes amoenus* Reuter has caused noticeable injury to ash seedlings in nurseries in the Lake States; the **tarnished plant bug**, *Lygus lineolaris* (Palisot de Beauvois), is often injurious to ornamentals and to forest nursery trees. It causes split-stem lesions on the stems of young *Populus*. The stems sometimes break at the lesion *(1054)*. Young, succulent growth of elm is frequently damaged by the feeding of *Neolygus invitus* (Say).

Seven plant bugs restricted to honeylocust were investigated in Pennsylvania, and the life history of the honeylocust plant bug, *Diaphnocoris chlorionis* (Say), is given along with biological observations on *Lopidea incurva* Knight, *Lygocoris tinctus* (Knight), *Pilophorus walshii* Uhler, *Plagiognathus delicatus* (Uhler), and

Taedia gleditsiae (Knight) *(1281)*. *D. chlorionis* has damaged and defoliated honeylocust in Michigan, New York, North Carolina, Ohio, Pennsylvania, Vermont, and Wisconsin. It is widely distributed from Quebec and Ontario to South Carolina, Mississippi, Texas, and in the North, west to Illinois, Indiana, and Iowa, and also California.

Plagiognathus albatus (Van Duzee), the **sycamore plant bug**, is the cause of unique injury to *Platanus* spp. over much of eastern North America. Small holes appear at feeding sites, giving the appearance of shotholes caused by defoliators, hail, or bacterial leaf spot *(1280)*.

Family Coreidae
Coreid Bugs

This is a large family of relatively large bugs, some members of which have the legs flattened and leaflike. They are similar to the lygaeids but differ in having numerous veins in the membrane of the hemelytra.

The **leaffooted pine seed bug**, *Leptoglossus corculus* (Say), occurs throughout the Eastern United States and is a major pest in southern pine seed orchards *(286, 360)*. Hosts include loblolly, shortleaf, slash, longleaf, Virginia, eastern white, pitch, Table Mountain, and spruce pines. Other pine species, native or introduced, grown in this region are also likely hosts. The large, conspicuous adults take flight with a loud buzzing sound when disturbed. Both adults and nymphs are reddish-brown to gray and have long legs. Adults are 15 to 18 mm in length, with a white zigzag line across the wings and flattened, leaflike hind tibiae. The cylindrical eggs are 2 mm long and about 1 mm in diameter. They are cream colored when first laid, but turn dark reddish-brown as the embryo develops. Usually about 20 eggs are laid end to end in a line along a single needle. There are several generations each year in the South. Nymphs and adults have piercing-sucking mouth parts that they insert into the conelets or cones to penetrate the developing ovules and seeds. Attacked cones show no external damage symptoms. In early stages, nymphs feed upon the needles and conelets. Second-stage nymphs destroy ovules in conelets, and extensive ovule destruction causes conelet abortion *(289)*. Third- , fourth- , and fifth-stage nymphs and adults feed primarily upon seeds within cones. Some seeds damaged in late summer and fall can be detected on radiographs *(287)*. However, in seed orchards, losses are also reflected by poor survival of conelet crops, high numbers of empty seeds, poor seed viability, and low yields of sound seeds per cone.

A related species, *L. occidentalis* Heidemann, a serious pest of Douglas-fir seed in California *(685)*, has been observed feeding on the needles and green cones of Austrian pine in Missouri.

Family Rhopalidae
Rhopalid Bugs

The **boxelder bug**, *Leptocoris trivittatus* (Say), often becomes a pest wherever boxelder is grown as a shade tree in the United States and Canada. In heavily infested areas, it will feed on ash and maple. Adults (fig. 19) are somewhat flattened, brownish black on top and about 12 mm long. There are also three red, longitudinal stripes on the thorax, the margins of the basal half of the wings are red, and the abdomen is bright red. Nymphs are wingless but possess wing pads and are dark toward the head. They have bright-red abdomens.

The winter is spent in the adult stage in dry, sheltered places, such as the attics of houses. During warm winter days, adults become active and come out of hiding, only to retreat again when it turns cold. During the spring, they emerge and fly to

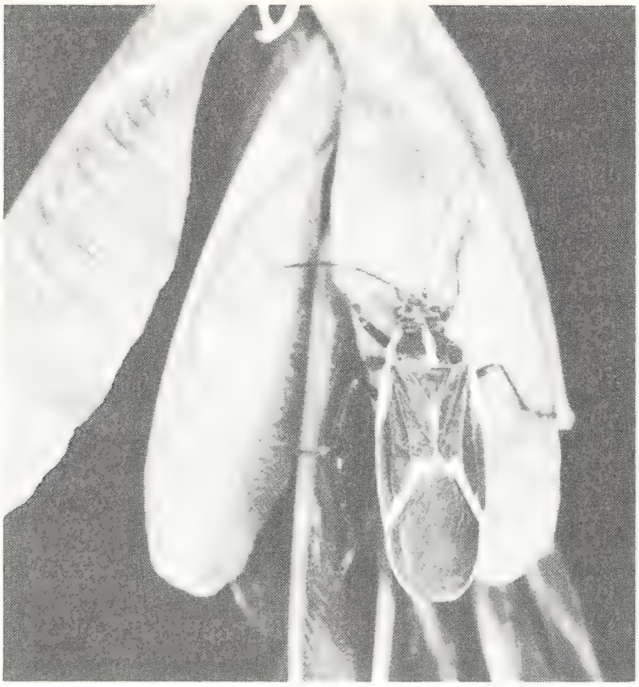


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Figure 19.—Adult of the boxelder bug, *Leptocoris trivittatus*, on seed of boxelder.

their hosts where they deposit eggs on the leaves. Eggs also are occasionally laid on leaves or under the bark of other tree species, on stones, grass, litter, fences, and in doorway crevices. Eggs hatch in 11 to 14 days and the nymphs feed on leaves, fruits, or soft seeds by inserting their beaks into the tissues. Feeding continues throughout the summer, or until the nymphs become adults. In some parts of the country the adults may emerge by midsummer and give rise to a second generation that matures in the fall.

The importance of the boxelder bug as a pest derives from its habit of invading houses in large numbers in search of shelter. Householders and supervisors of outdoor recreational areas and parks are often concerned. One way to reduce the problem is to remove the boxelder trees, particularly the female seed-bearing trees. The removal of leaf litter also discourages the insects from congregating *(1350)*.

Family Lygaeidae
Lygaeid Bugs

This is a rather large family, most members of which feed on mature seed. The adults are small insects, about 2 to 18 mm long. Many are conspicuously marked with spots or bands of white, black, or red. Various plant-feeding species are found on herbaceous vegetation in the forest. One species, *Kleidocerys resedae geminatus* (Say), feeds on the catkins of yellow and gray birches, rhododendron, etc.

Family Thaumastocoridae
Thaumastocorid Bugs

Xylastodoris luteolus Barber, the **royalpalm bug**, is the only member of this family known to occur in the United States. It feeds on the Florida royalpalm, *Roystonea elata* (Bartr.) F. Harper, in southern Florida, as well as in its native land, Cuba. Adults are pale yellow, flattened, and about 2 to 2.5 mm long. Eggs are deposited on the undersurfaces of leaflet midribs, usually on older trees. Feeding occurs on unfolded leaflets of newly emerging fronds and to some extent on the spike or projecting part of the terminal bud. Fronds exposed to heavy feeding may turn brown *(54)*.

Order Homoptera—*Aphids, Spittlebugs, Scale Insects, and Allies*

The order Homoptera consists of divergent groups, some of which are among the most common and abundant of all insects. Except for the cicadas, they are mostly small and inconspicuous. A few are brilliantly colored, and many are grotesque in shape. They are closely related to members of the order Hemiptera, but are distinguished by their uniformly textured wings and by the point of origin of the beak at the back of the underside of the head. The mouth parts consist of four piercing stylets (the mandibles and maxillae). Many species are wingless, at least in the female. When wings are present, there are usually four with the front pair longer and the hind pair often wider. The wings do not overlap much at the top, and their bases are never abruptly thicker than their tops. They usually slope roof-shaped over the abdomen while the insect is at rest. Members of many families are able to conceal themselves beneath various protective coverings such as froth, waxy tufts, hard waxy shells, and the sloughing epidermis of bark. The majority are also able to produce honeydew, a sweet sticky excretion.

Homopterous insects differ greatly in their biologies; some species produce several generations per year while others may require several years to complete one life cycle. The life history of some species is also very complex, involving both bisexual and parthenogenetic generations, winged and wingless individuals and generations, and sometimes the regular alternation of food plants. However, all species are phytophagous, and they feed on an almost endless variety of plants of all sizes and ages. They feed by inserting their beaks into plant tissues and extracting the sap. A large number of species are injurious both to cultivated crops and to forest, shade, and ornamental trees.

Family Flatidae
Flatid Planthoppers

A number of species of flatid planthoppers feed on trees and shrubs, but they are seldom of economic importance *(949, 1229)*. Members of different genera differ greatly in body and form. Those occurring in this country are usually less than 12 mm long, and many have the head greatly modified, with the part in front of the eyes greatly enlarged and snoutlike. A useful characteristic for recognizing them is the position and form of the antennae. The two basal segments are stout, whereas the remainder consists of a nearly pear-shaped basal segment and a segmented, bristlelike terminal part. They also have a few large spines on the hind tibiae. Two fairly common species are *Anormenis septentrionalis* (Spinola) and *Metcalfa pruinosa* (Say). The nymphs, which feed on the undersurfaces and midribs of leaves, resemble small masses of cotton and are about 6 mm in diameter. They jump when disturbed.

Family Cicadellidae
Leafhoppers

This is one of the largest families of insects in the world; all appear to be plant-feeders. The adults range in length from about 3 to 15 mm and come in an almost endless variety of colors. Certain species resemble flatid planthoppers, but they differ in having one or more rows of small spines extending the length of the hind tibiae. Because of the nature of their feeding, which consists of piercing plant tissues with their mouth parts and sucking the juices, the damage they cause is usually not recognized or is attributed to other factors. About the only visible effects of leafhopper feeding are the white stippling of foliage or the browning,

withering, and curling of leaves. Because of the difficulty in observing or evaluating the damage to trees, very little is known of its magnitude or importance. The probability is that it is grossly underestimated. These insects, in fact, may contribute significantly to the general unproductiveness of many stands of valuable hardwoods in the Eastern United States. Many species are also vectors of destructive plant diseases, especially diseases of viral, mycoplasmal, or rickettsial origin.

Some species of leafhoppers spend the winter in the egg stage; others, as adults. Nymphs usually hatch from overwintering eggs in May or June, and then feed on new, tender leaves. Overwintering adults emerge during the first warm days in spring and lay eggs as soon as the leaves of their hosts are fully developed. Nymphs hatch in about 10 days. As a rule there are one or two generations per year; sometimes, more.

Forest and shade trees serve as hosts for many species of *Erythroneura, Empoasca,* and *Typhlocyba (295).* Several species of *Idiocerus* feed on willow and poplar. Various species of *Macropsis* feed on poplar, willow, and honeylocust. Certain species of *Scaphoideus, Gyponana,* and *Ponana* occur on American elm; oaks are infested by species of *Alebra, Eutittix,* and *Penthimia.* This is only a partial listing of genera and species known to attack trees; the total number is far greater.

The most important leafhopper as far as forest and shade trees are concerned is the **whitebanded elm leafhopper**, *Scaphoideus luteolus* Van Duzee, the vector of elm phloem necrosis, a mycoplasmal disease of American elm *(43).* Adults are difficult to separate from those of closely related species, but not so the nymphs (fig. 20). After the second instar, practically all of the nymphs are dark brown with a transverse white band across the dorsum. This band lies just behind the thorax and covers the first two and part of the third abdominal segments. The species is widely distributed in the Eastern United States, from New York west to Kansas, Nebraska, and Iowa, and south to Georgia and Alabama.

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Figure 20.—Adult and nymph of the whitebanded elm leafhopper, *Scaphoideus luteolus.*

The whitebanded elm leafhopper lays its eggs in the cork parenchyma of elm bark. When the nymphs hatch, they wander in search of leaves on which to feed. The first of these to be found usually are on tiny branchlets growing from the trunk. A dozen or more young nymphs may be found clustered on the undersurface of one of these leaves, where they feed on the midribs or larger veins. Excessive feeding often causes the apical portions of the leaves to turn brown and die. Older nymphs are more widely distributed throughout the crown of the tree *(44)*.

Elm phloem necrosis mycoplasm is transmitted by the adults that feed first on the leaves of diseased trees and then on the leaves of healthy trees. Studies have shown that a period of several days must elapse after the insect feeds on a diseased tree before it can transmit the mycoplasm. Not all of the details of the life cycle of the species have been determined, but it is known that the winter is spent in the egg stage and that there is only one generation per year.

Homalodisca coagulata (Say), *Oncometopia orbona* (F.), *Cuerna costalis* (F.), and *Graphocephala versuta* (Say) transmit the rickettsia causing phony peach, a destructive disease of peach trees in the South.

Family Membracidae
Treehoppers

Treehoppers are characterized by the prolongation of the pronotum backward and above the abdomen. In some species it not only extends backward but also sidewise and upward, and in some, it extends to the top of the abdomen and completely covers the wings. The hindlegs are long and adapted for jumping, and the female's ovipositor is long and sawlike. The majority of species apparently live on trees, most often in open stands but also in woods. Only a few species are of economic importance. The species of treehoppers found in Connecticut and Ohio have been discussed *(456, 950)*.

The **buffalo treehopper**, *Stictocephala bisonia* Kopp & Yonke, is occasionally injurious to young ash and elm trees. Injury results from two opposing slits cut in the bark by the female during oviposition. Eggs are placed in the slit, and the portion of the stem beyond it often dies. Adults are light green to yellowish and about 9 mm long. The pronotum is sharply elevated, is widest at the tip, bears two sharply pointed horns that extend at right angles to the body, and ends beyond the tip of the abdomen in a narrowed acute process.

The **threecornered alfalfa hopper**, *Spissistilus festinus* (Say), occasionally damages black locust seedlings in nurseries in the South. Injury results from nymphs feeding on the stems, usually 25 to 50 mm above the base. Gall-like swellings or calluses that develop just above the feeding punctures kill many of the seedlings. Other seedlings are lost when they break at these points. *Stictocephala militaris* (Gibson & Wells) nymphs feed on the veins and petioles of sweetgum leaves in north Georgia. Gall-like enlargements may develop at points of injury on the petioles, or the leaves may die. Other common membracids and their tree hosts are as follows: *Micrutalis calva* (Say)—abundant on honeylocust; *Telamona reclivata* Fitch—common to abundant on basswood; *T. decorata* Ball—fairly common on quaking aspen; *Vanduzeea arquata* (Say) and *Thelia bimaculata* (F.)—abundant on black locust; *Cyrtolobus discoidalis* (Emmons)—common on red oak; *Carynota stupida* (Walker)—sometimes abundant on yellow birch; *Platycotis vittata* (F.)—abundant on oak; and the **twomarked treehopper,** *Enchenopa binotata* (Say)—common on butternut but also attacks walnut.

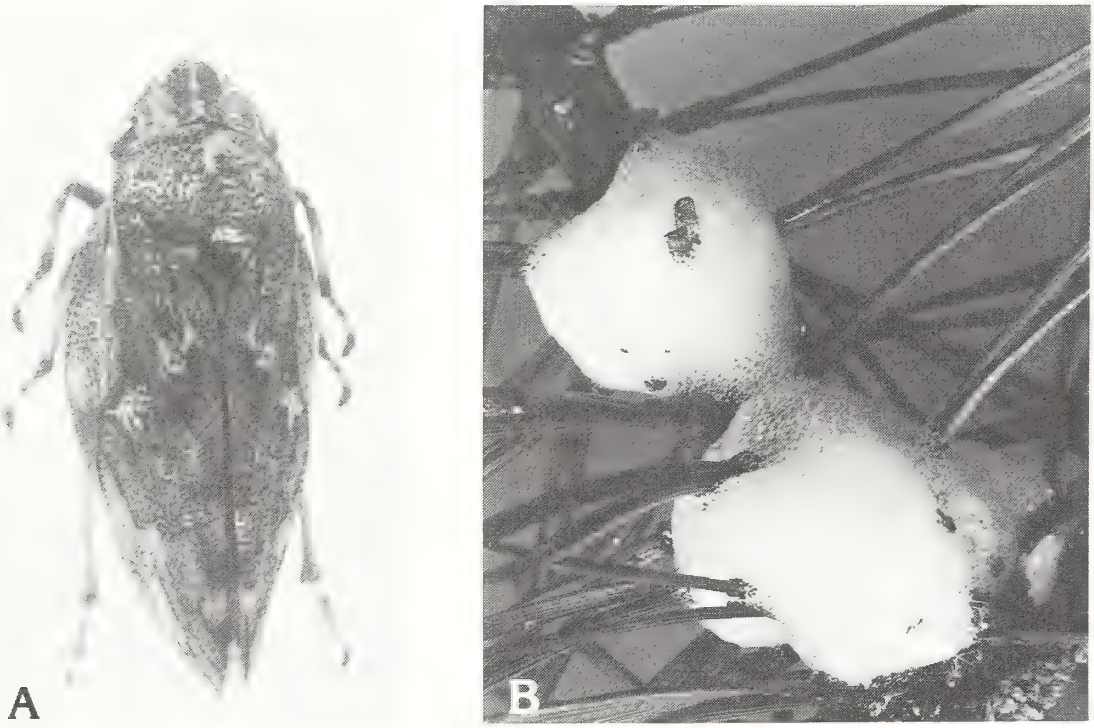
Family Cercopidae
Spittlebugs

Spittlebugs are represented in our fauna by 25 species *(1148)*. As a group, the adults are stout-bodied, rarely over 12 mm long, oval or oval-elongate, and dull colored. The nymphal or immature stages are spent in frothy masses of spittle on their host plants. The genus *Aphrophora* is undergoing revision *(518)*.

The **pine spittlebug**, *Aphrophora parallela* (Say), occurs in southern Canada and throughout most of the Eastern States from New England to the Lake States, Arkansas, Florida, and Alabama. Its favorite host appears to be Scotch pine, but it is also known to attack pitch, eastern white, Virginia, jack, slash, loblolly, and Japanese pines; Norway, white, and red spruces; and balsam fir, larch, and eastern hemlock. Trees of all ages and sizes are attacked. During outbreaks, infested Scotch pines may be severely stunted or killed *(1138)*. Adults are tan to dark reddish-brown with two narrow, oblique, light bands, usually bordered by darker bands, on each wing cover, and are about 8 to 11 mm long (fig. 21).

Eggs are deposited in dead woody tissue or just under the bark of twigs during July and August. In the northern parts of its range, the species spends the winter in the egg stage. The nymphs usually hatch in May, and then feed on the twigs, where they soon cover themselves with spittle. As they grow, they usually change locations and form new masses of spittle at each stop. Upon the approach of maturity they often move the the main trunk where several may occupy a single spittle mass. When full grown, they migrate to the needles and transform to adults. Adults are present during July and August and feed on the same hosts without producing spittle masses. There is one generation per year.

The fungus, *Entomophora aphrophorae* Rostrup, and high temperatures during the nymphal period occasionally cause heavy mortality of the pine spittlebug. The pine spittlebug is often associated with *Diplodia pini*, a fungus that apparently invades the tree when weakened and through the insect's feeding punctures. Most



Courtesy Conn. Agric. Exp. Stn.

Figure 21.—A, adult; B, nymphal spittle masses of the pine spittlebug, *Aphrophora parallela*.

flagging injury attributed to the spittlebug, in the Lake States at least, is due to the fungus rather than the insect. Controlling the insect halts the disease spread. The problem is worst in weakened large sapling and pole-size Scotch pine stands. Thinning closed stands to make them more vigorous is also recommended as a control practice.

The **Saratoga spittlebug**, *Aphrophora saratogensis* (Fitch), occurs in southeastern Canada and the East Central United States from Maine to Minnesota. Nymphs feed on a wide variety of herbs and shrubs. Sweetfern is preferred and necessary for most outbreaks. Outbreaks can occur, however, when 80 percent of the forest floor is covered by other broadleaf plants. The adults feed on red, jack, eastern white, Virginia, pitch, and loblolly pines, and occasionally on white spruce, balsam fir, and tamarack. In the Lake States, red pine is hit hardest and jack pine ranks second. Heavy infestations in the Lake States have destroyed entire red pine plantations.

The adult is about 9 to 10 mm long, light brown to tan, with a light, irregular arrow-shaped stripe on the head and pronotum and with oblique, wavy markings on the wing covers. The abdomen of the young nymph is scarlet, edged with black. Fifth instars are dark brown.

Adults are active from late June to late September. They feed by inserting their mouth parts into the cortex of new and old shoots of the host, mostly on 2-year-old internodes. They extract sap and inject toxic saliva which causes the formation of necrotic resin-filled pockets in the pholem and xylem tissues. Damaged pines are characterized by the presence of reddish-brown "flags" of dead foliage, by numerous puncture wounds on the twigs covered with small drops of resin, and by light-tan flecks in the wood and inner bark at feeding points. Extensive feeding kills branches, stunts and deforms growing shoots, and may kill entire trees. Mortality usually begins 2 or 3 years after the first flags are seen *(389)*.

On red pine, eggs are laid under the outer scales of buds on the upper part of the tree. On jack pine, they are laid in the sheaths of current year's needles or under the bark of twigs. The winter is spent in the egg stage and the nymphs hatch in the spring just about the time red and jack pine buds begin to elongate. Young nymphs drop to the ground and begin feeding at the base of alternate host stems, either singly or in small groups. As they feed, they form masses of spittle (fig. 22). To find these masses it is frequently necessary to brush the litter away from the base of

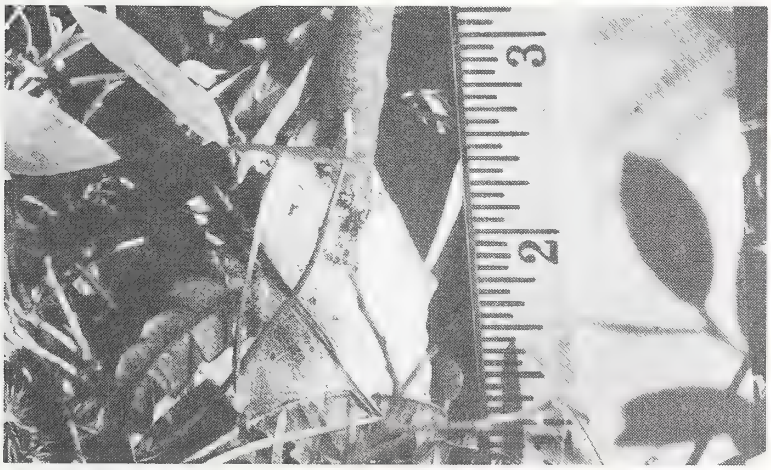


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Figure 22.—Spittle mass of the Saratoga spittlebug, *Aphrophora saratogensis*, at base of sweetfern.

the stem. The nymphs reach maturity and transform to adults in about 40 to 70 days, depending on the weather. The adults then fly to the pine hosts and begin feeding on needle-bearing twigs. In the Lake States, adult transformation is about 80 percent complete by early to mid-July.

Nymphal populations are sometimes reduced by late spring frosts in the Lake States. Hot, dry weather also kills many young nymphs, especially in open plantations. Insect parasites and predators provide a certain amount of control but are unable to prevent outbreaks. Recommended preventive control measures include selection of sites for red or jack pine plantations that are comparatively free of hosts favored by the nymphs, dense planting to secure early crown closure, and planting on good sites. Methods of direct control of adults and nymphs are available *(1334, 1335)*.

Prosapia bicincta (Say) occurs from Massachusetts to Florida and west to Kansas and Texas. Adults are dark brown and about 9 mm long. There usually are two distinct bands across the wings and a narrower orange band on the thorax between the humeral angles. Adults have been recorded feeding on holly, redbud, cherry, and a wide variety of other woody and herbaceous plants. Infested leaves of holly become distorted, stunted, and discolored and may have necrotic areas at feeding sites.

Clastoptera undulata Uhler nymphs and adults have been observed feeding on the young twigs of horsetail casuarina in Florida. In heavily infested areas, the adults may be attracted to lights in such large numbers that they become a nuisance. The **alder spittlebug**, *C. obtusa* (Say), a common species, feeds on various shrubs and trees, including hickory, birch, and alder. The **pecan spittlebug**, *C. achatina* Germar, is occasionally a serious pest of pecan in the Midwest. It feeds on the terminals, sometimes killing fruit-producing shoots. The **dogwood spittlebug**, *C. proteus* Fitch, has been recorded on pine. *C. salicis* (De Geer) frequently occurs in large numbers on willow. The **meadow spittlebug**, *Philaenus spumarius* (L.), occasionally feeds on Scotch pine in the Northeast.

Family Cicadidae
Cicadas

Cicadas are the largest members of the order Homoptera in the United States. The adults are stocky, heavy-bodied insects with large compound eyes and membranous wings, and some reach a length of 50 mm. There are two common types, (1) the dog-day cicadas, often called harvest flies, and (2) the periodical cicadas, also known as 17-year locusts. The dog-day group contains large blackish species, usually with greenish markings. The life cycle lasts from 2 to 5 years but, because of overlapping broods, some adults appear every year. Periodical cicadas differ from the dog-day group in being smaller and in having reddish eyes, reddish legs, and reddish wing veins. The life cycle is 13 years in the South and 17 years in the North.

Cicadas deposit their eggs in the twigs of trees and shrubs and often damage twigs so severely that their terminal portions die. When the eggs hatch, the young nymphs drop to the ground, enter the soil, and feed on roots. Here the nymph remains until ready to molt for the last time, years later. Before molting, it emerges from the ground and climbs upon some object, usually the trunk of a tree, fastens its claws in the bark, and molts. The adults of some species live 5 to 6 weeks.

The **periodical cicada**, *Magicicada septendecim* (L.) (fig. 23A), is widely distributed in the Eastern United States, and it lays its eggs in more than 70 species of trees and other plants. The most susceptible of the trees appear to be the oaks,

hickory, honeylocust, dogwood, apple, and peach; however, many others such as sweetgum, elm, ash, yellow-poplar, walnut, sycamore, and redbud may also be heavily attacked. Adults are about 40 mm long. The female is completely black on top, but the male has 4 or 5 orange-brown abdominal segments on top.

A

B

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Figure 23.—The periodical cicada, *Magicicada septendecim*: A, adult; B, oviposition scars in white oak twig.

The female uses a sawlike ovipositor to puncture the bark and make a pocket in the wood in which she deposits from 24 to 28 eggs in two rows. She may then proceed along the twig and repeat the process until she has deposited about 5 to 20 batches of eggs. Sometimes the punctures are placed so close together that the wounds appear as a single slit up to 75 mm long (fig. 23B). When the eggs hatch, the nymphs fall and enter the ground where they feed on suitable roots. Usually they are found at depths of about 0.5 m beneath the surface. When they become full grown, they emerge to begin a new cycle, usually leaving the ground during the night. Emergence may begin as early as the last week of April in the South and as late as the last week in May in the North.

A few days after the adults appear, the males begin drumming or singing. During outbreaks the sound is loud and incessant, literally deafening in wooded areas. The chorus begins at dawn and the volume increases as the temperature rises. It ceases at evening.

Cicada adults cause no visible feeding damage. In contrast, the egg-laying habits of the female may cause serious damage, especially to young, transplanted trees in nurseries and orchards. Some damage also results to older trees. Damaged twigs wilt, and some break at damaged points. Methods of control are discussed *(1220)*.

Magicicada cassini (Fisher) also occurs in the Eastern United States. In Kansas, it is found mainly in streamside habitats in lowland forests. *Tibicen canicularis* (Harris) has been reported causing serious damage in white spruce plantations on poor sites in Quebec.

Family Psyllidae
Jumping Plantlice

Jumping plantlice or psyllids are very small, about 2 to 5 mm long, and look very much like minature cicadas. There is also some resemblance to winged aphids but psyllids differ in having stouter legs, with the hind pair adapted to jumping. The nymphs of certain species which secrete large quantities of wax resemble woolly aphids. The adults are very active and jump or fly when disturbed.

Psyllids fall into two species groups: (1) the leaf gall makers, and (2) the woody gall makers. Adults of the leaf-feeding forms emerge from galls in the fall; the wood-feeding forms emerge in spring. Leaf gall makers are further subdivided into two groups, blister gall makers and nipple gall makers.

Pachypsylla celtidisvesicula Riley, the **blistergall psyllid**, forms a small, monothalamous (one psyllid per gall) blister gall. It is believed to occur throughout the range of hackberry in the United States and is the most abundant of the hackberry psyllids. Fifty or more may infest a single leaf. Adults often become a household nuisance when thousands accumulate on screens in the autumn before hibernating. Two undescribed species of blistergall psyllids occur on sugarberry and netleaf hackberry.

Pachypsylla celtidisasterícus Riley, the **hackberry stargall**, produces a gall that closely resembles the blistergall formed by the blistergall psyllid, except that it has starlike growth on the lower side of the leaf. It can occur on all hackberry tree species except *Celtis occidentalis* L.

The **hackberry nipplegall maker**, *P. celtidismamma* (Riley), is perhaps the best known hackberry psyllid. It is found only on *C. occidentalis*. There are other nipplegall makers on the other four species of hackberry trees, but they are not this species. It is monothalamous, although at times it may appear to be polythalamous because as many as seven galls of another psyllid, *P. celtidisvesicula*, may be incorporated into a single nipplegall of *P. celtidismamma (890)*. Like the blistergall psyllid, adults cluster on screens during the fall. The nipplegall psyllid may disfigure leaves when infestations are heavy *(1112)*.

Pachypsylla celtidisgemma Riley, the **budgall psyllid**, occurs throughout the range of hackberry trees in the United States, and may become a pest when populations are high. Adults appear during the latter part of June in the New York City area and lay their eggs on the young leaves. Young nymphs enter the buds and initiate gall formation. The polythalamous galls contain several nymphs, each in its own chamber. The winter is passed as a fifth nymphal instar in the gall *(1243)*.

Pachypsylla venusta (Osten Sacken), the **petiolegall psyllid**, is the largest of the hackberry psyllids, and it forms the largest galls. The galls are polythalamous and usually contain 6 cells, although there may be as many as 30. These galls may persist on the trees for several years and seriously damage their appearance. Distribution of the species is mostly limited to below the 40th parallel.

Pachypsylla celtidisinteneris Mally forms small, inconspicuous, monothalamous galls under the bark of hackberry twigs.

Several other species in the genus *Psylla* feed on various trees, shrubs, and ornamentals, and produce large quantities of honeydew that drips and covers their hosts. A black mold growing in this material often makes infested plants look less healthy than they are.

The **boxwood psylиd**, *Psylla buxi* (L.), attacks American and English varieties of boxwood and probably occurs wherever they grow. The adult is greenish and has transparent wings; nymphs are gray-green and covered with a white cottony or

waxy material. The first winter is spent in the nymphal stage. Feeding is resumed in the spring and adults begin to emerge in early May. Infested leaves curl and form cups in which nymphs are concealed. Feeding also results in reduced growth of young twigs. Eggs are laid under bud scales during July and August. Control recommendations are available *(1269)*. Other species of *Psylla* and their hosts include: *P. annulata* Fitch—paper birch and maple; *P. carpinicola* Crawford—birch; *P. floccosa* Patch and *P. galeaformis* Patch—alder; and *P. trimaculata* Crawford—cherry.

Trioza tripunctata (Fitch) has been observed feeding on the needles of pines in ornamental plantings in Connecticut. Damage consists of yellowish or reddish spots that frequently coalesce, causing the needles to die and drop prematurely. The **persimmon psylla**, *T. diospyri* (Ashmead), and *T. magnoliae* (Ashmead) feed on persimmon and magnolia, respectively, in Florida.

More than 150 species of hymenopterous and dipterous parasites attack psyllids in the United States *(639)*.

Family Aphididae
Aphids, Plantlice

The aphids or plantlice constitute a very large group of small, soft-bodied insects that feed by sucking the sap from the leaves, stems, and roots of plants and trees. They are pear-shaped or globular, have fairly long antennae, and usually a pair of tubelike cornicles rise from the top of the fifth or sixth abdominal segment. Winged males are common. The wings are very delicate and membranous, with only a few simple veins, and they are usually held vertically above the body while at rest. Egg-laying females of many species are also winged.

Ordinarily, most of the aphids feed while exposed on their hosts. Others feed in sheltered locations such as inside leaves, which they cause to curl or to become distorted, or inside galls. Trees of all kinds, sizes, and ages are attacked, but they normally are not seriously injured. Serious damage sometimes results, however, especially to shade and ornamental trees and young trees in plantations. Honeydew dropping from heavily infested shade and ornamental trees is often a nuisance because it forms a sticky coating on everything below, especially sidewalks, parked automobiles, and park benches. Additional damage may result from the growth of a sooty mold in the honeydew. It not only detracts from the esthetic value of shade trees and ornamentals, but also interferes with the food-manufacturing process of their leaves. However, honeydew is also useful as food for many species of beneficial insects. Numerous publications have been issued on the identity, distribution, and hosts of aphids *(603, 955, 962, 963, 964, 965, 978)*. Nomenclature cited in this section is based upon that set forth in "Survey of the World's Aphids" *(353)*.

The **giant bark aphid**, *Longistigma caryae* (Harris), one of the largest of all North American aphids, occurs throughout much of the Eastern United States and feeds on a variety of deciduous trees such as elm, pecan, sycamore, oak, maple, basswood, birch, beech, walnut, and willow. Adults are about 6 mm long, and are covered with a bluish-white bloom. Males are winged; egg-laying females are wingless. Eggs are laid on twigs, a single female laying many. The aphids usually occur in clusters on the undersides of twigs and small limbs. Depending on locality, there may be several generations per year. Heavily infested twigs may be seriously injured or killed.

The genus *Cinara* contains a number of conifer-infesting species that feed on the bark; only a few of these are mentioned here.

The **white pine aphid**, *C. strobi* (Fitch), occurs from New England to the Lake States and Carolinas and feeds on eastern white pine. Winged forms are almost 4 mm long. The body is shiny dark brown, with a white stripe down the middle of the dorsum and white powdery spots on the sides, and it bears long stiff hairs.

During the fall, winged aphids lay their eggs end to end along the needle. As many as 27 may be found on a single needle, although 5 or 6 are generally more common. Hatching occurs in the spring, and wingless females produce living young which live in colonies up to 75 or 100 mm long clustered around a branch or the leader. Several generations later, winged females are produced and they migrate and also produce living young. Toward the fall, winged males and females mate, and a new crop of overwintering eggs is laid. Young trees or individual branches of large trees may be killed by heavy infestations or their growth may be seriously reduced.

Cinara sabinae (Gillette & Palmer), a small yellowish species about 3 mm long and covered with a white powdery secretion, feeds on redcedar in the Eastern United States. Colonies are usually found on twigs and small branches. Heavily infested trees often become unsightly as a result of black mold developing in honeydew on the foliage. The related species, *C. canadensis* Hottes & Bradley and *C. juniperivora* (Wilson), also feed on redcedar.

Cinara pinea (Mordwilko) is a large reddish-brown species with numerous dark specks and a pair of large spots behind the cornicles. It has been recorded feeding on young Scotch, red, and Virginia pines. Additional pine-infesting species of *Cinara* include *C. atlantica* (Wilson) on loblolly, shortleaf, Virginia, slash, longleaf, pond, sand, and spruce pines in the South, and Scotch, pitch and Table Mountain pines in the North; *C. taedae* Tissot on loblolly, Virginia, slash, sand, spruce, pond, Table Mountain, and pitch pines; *C. watsoni* Tissot on loblolly, shortleaf, slash, spruce, pond, red, Scotch, Virginia, sand, jack, pitch, and Table Mountain pines; *C. pinivora* (Wilson) on loblolly, slash, Virginia, shortleaf, sand, spruce, pond, pitch, red, jack, and Table Mountain pines; and *C. pergandei* (Wilson) on loblolly, Virginia, shortleaf, sand, spruce, pitch, and jack pines. *C. pergandei* is perhaps the most common bark aphid on Virginia pine. Pine-infesting aphids that attack the needles include *Eulachnus rileyi* (Williams), the **powdery pine needle aphid**, on Scotch, red, pitch, Virginia, shortleaf, loblolly, slash, and eastern white pines; *E. agilis* (Kaltenbach) on red, Scotch, Austrian, and eastern white pines; *Essigella pini* (Wilson), the **speckled pine needle aphid**, on loblolly, slash, and pond pines in Florida (also recorded from Maryland and Pennsylvania); *Schizolachnus piniradiatae* (Davidson), the **woolly pine needle aphid**, on jack and red pines in the Eastern States.

Several other species of aphids have also been recorded on other conifers. For example, *Cinara confinis* (Koch) has been recorded on fir; *C. pilicornis* (Hartig) on Norway spruce and various firs; *C. tujafilina* (Del Guercio) on northern white-cedar, baldcypress, and other species (heavy infestations have been recorded in nurseries in Florida and Delaware); *Prociphilus bumelia* (Schrank) on balsam fir, as well as roots of eastern white pine; and the **balsam twig aphid**, *Mindarus abietinus* (Koch), on a wide variety of hosts including balsam fir, Fraser fir, Siberian fir, subalpine fir, white spruce, and juniper. On fir, damaged needles curl and the bark of heavily infested twigs becomes roughened *(919)*.

The **boxelder aphid**, *Periphyllus negundinis* (Thomas), feeds on the leaves and twigs of boxelder wherever it grows in the United States and Canada. The aphid's body is usually yellowish green with brownish marks on the thorax and abdomen.

Walks, benches, or cars parked beneath infested trees are often badly soiled. The related species, the **Norway maple aphid**, *P. lyropictus* (Kessler), often completly defoliates Norway and sugar maple trees. Honeydew dripping from infested leaves is a nuisance. *P. americanus* (Baker); *Drepanaphis carolinensis* Smith; *D. nigricans* Smith; *D. sabrinae* Miller; the **painted maple aphid**, *D. acerifoliae* (Thomas); and *Drepanosiphum platanoidis* (Schrank), the **sycamore maple aphid**, are also found on maples.

Numerous species of *Myzocallis* such as *M. bellus* (Walsh), the **greater striped red oak aphid**; *M. punctatus* (Monell); *M. discolor* (Monell); and *M. melanocera* Boudreaux & Tissot feed on various oaks. Other common members of related genera and their hosts include: *Pterocallis alnifoliae* (Fitch)—alder; *Eucallipterus tiliae* (L.), the **basswood aphid**—native and introduced lindens; the **crapemyrtle aphid,** *Tinocallis kahawaluokalani* (Kirkaldy)—crapemyrtle; the **black pecan aphid**, *Melanocallis fumipennellus* (Fitch)—hickory and pecan; and the **elm leaf aphid**, *Tinocallis ulmifolii* (Monell)—elm.

Many other species of free-living aphids also occur commonly on various deciduous trees. These include the **black-margined aphid**, *Monellia costalis* (Fitch), *M. caryella* (Fitch), *M. microsetosa* Richards, and *M. nigropunctata* Granovsky on hickories; *Chaitophorus stevensis* Sanborn, *C. populicola* Thomas, and *Tuberolachnus salignus* (Gmelin) on poplars; *Pterocomma populifoliae* (Fitch) and *P. smithiae* (Monell), the **black willow aphid**, on poplars and willows; *P. salicis* (L.), on willow; the **tuliptree aphid**, *Illinoia liriodendri* (Monell), on yellow-poplar and magnolia; the **cowpea aphid**, *Aphis craccivora* Koch, on black locust seedlings; *Phyllaphis fagi* (L.), on nearly all species of beech; *Calaphis betulaecolens* (Fitch), the **common birch aphid**, on birch (often in large numbers); *C. betulella* Walsh, on birch and beech; *Euceraphis punctipennis* (Zetterstedt), the **European birch aphid**, on various birches, especially yellow birch; *E. lineata* Baker, on gray birch; and *E. mucida* (Fitch), on river birch.

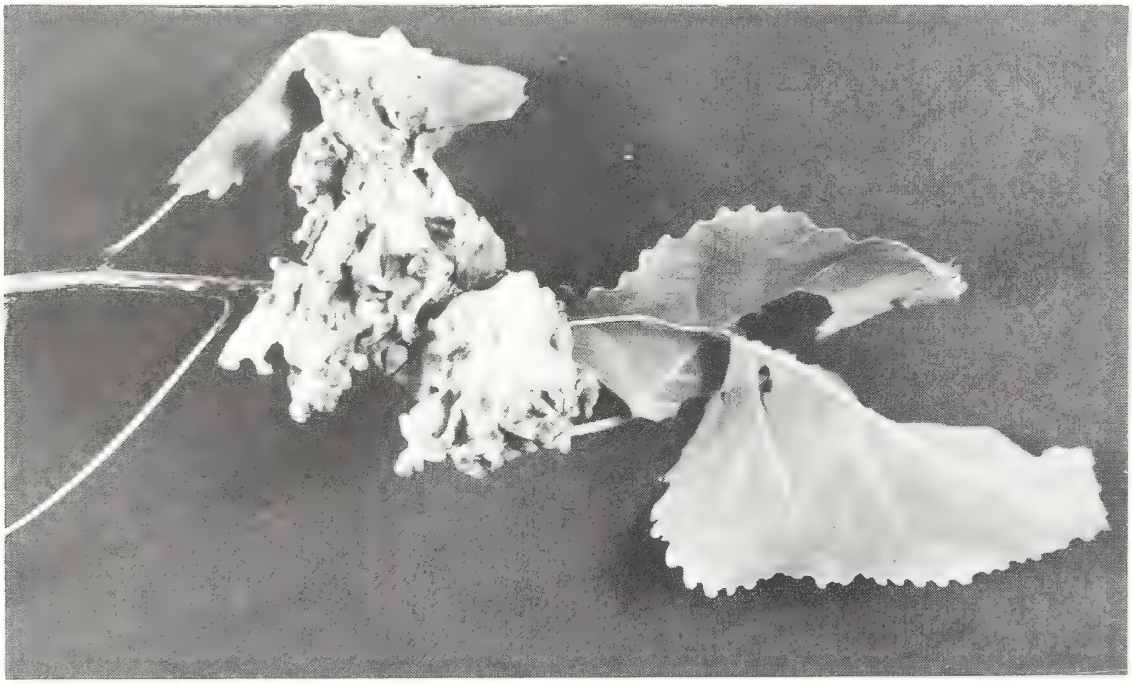
Three species of woolly aphids are commonly found on elms in the Eastern United States. The **woolly apple aphid**, *Eriosoma lanigerum* (Hausmann), feeds on new terminal leaves, causing them to curl or appear in the form of rosettes. It attacks apple, pear, hawthorn, and mountain-ash. Damage to elms is not especially severe. The presence of large numbers of distorted leaves on shade trees is unsightly. The **woolly elm aphid**, *E. americanum* (Riley), has elm as a primary host and serviceberry as an alternate host. It feeds at the edges of young elm leaves in the spring, causing them to swell, curl, and roll inward from the edge. Two generations are produced on elm. Members of the second generation then fly to serviceberry and attack its roots. The summer is spent here. During the fall, a winged generation develops and flies back to the elm, where it lays a cluster of overwintering eggs. *E. rileyi* Thomas, the **woolly elm bark aphid**, attacks American and slippery elms. It occurs in dense woolly clusters on the limbs and trunks, causing knotty growths to form at the sites of injury. Heavily infested trees may be seriously injured. Hawthorn is infested by the closely related species, *E. crataegi* (Oestlund). It occurs in dense colonies in twigs and branches and is occasionally injurious to ornamentals.

Several other woolly aphids are also found on various species of hardwoods. The **beech blight aphid**, *Fagiphagus imbricator* (Fitch), feeds primarily on the bark of twigs and small branches, but also can be found on the trunk and undersides of leaves of beech trees from New England to Georgia and Illinois. Its body is covered with a white, cottony substance that strings out in fairly long threads and forms a

tuft at the rear end. Heavy infestations occasionally develop on forest-grown trees. The **woolly alder aphid**, *Prociphilus tessellatus* (Fitch), occurs throughout the Eastern United States and is often abundant on alder and silver maple. *P. fraxinifolii* (Riley) feeds on ash and *P. corrugatans* (Sirrine) on serviceberry. *P. longianus* Smith is associated with root galls caused by cancer-root on black oak.

Certain species of aphids produce galls by their feeding. The **elm cockscombgall aphid**, *Colopha ulmicola* (Fitch), is probably the most important tree-infesting species. It occurs throughout most of the United States and Canada wherever its hosts, American, rock, and slippery elms, grow. In early summer, it feeds on leaves, causing the formation of galls up to 25 mm long and 6 mm in height. The gall is irregular in shape and resembles a rooster's comb. The winter is spent in the egg stage on elm, and by midsummer the aphids have left for a secondary host thought to be a grass. There are six generations per year. Damage is not severe, but when large numbers of galls occur on the leaves of young trees and ornamentals, the trees may become unattractive. Another species, *Tetraneura ulmi* (L.), produces pedunculated, bladderlike galls up to 25 mm long on the upper surfaces of leaves in New England.

The **poplar vagabond aphid**, *Mordwilkoja vagabunda* (Walsh), feeds at the tips of twigs of cottonwoods and occurs from New England to Utah, causing the formation of convoluted galls (fig. 24) up to 13 cm in diameter. These galls may occur singly or in clusters of three to five each. The winter is usually spent in the egg stage in old galls or occasionally in nearby bark crevices *(623)*. Other gall-producing aphids include *Hormaphis hamamelidis* (Fitch), which forms conical galls on the upper surfaces of witch-hazel leaves; *Hamaelistes spinosus* Shimer, the **witch-hazel gall aphid**, which causes galls to form on the stem buds of witch-hazel; *Kaltenbachiella ulmifusa* (Walsh & Riley), which forms spindle-shaped, saclike galls on the upper surfaces of leaves of slippery elm; and the **poplar petiole gall aphid**, *Pemphigus populitransversus* Riley, which occurs on various species of poplar where it overwinters and produces oval galls on the leaf petiole.



F-506747

Figure 24.—Galls of the poplar vagabond aphid, *Mordwilkoja vagabunda*, on poplar.

Family Adelgidae
Adelgids

Members of this family differ morphologically from true aphids in having shorter antennal segments and lacking cornicles. Unlike the Aphididae, both sexually perfect and imperfect female adelgids lay eggs. All species occur only on conifers. Feeding sites of important eastern adelgids include needles, twigs, limbs, trunks, or the inside of galls.

The **eastern spruce gall adelgid**, *Adelges abietis* (L.), an introduced species from Europe, occurs in southeastern Canada and in the Northeastern and Lake States. Its preferred host appears to be Norway spruce, but it is also found occasionally on white, red, and blue spruces. It overwinters as small nymphs under coverings of waxy threads at the bases of buds on the undersides of twigs *(1290)*. The nymphs molt in the spring and become stem-mothers that lay eggs on the needles about the time the buds are ready to break. Hatching occurs in about 2 weeks and the young nymphs crawl to the bases of new needles. Here they feed, causing the formation of pineapple-shaped galls *(988)* in which they live and continue their development (fig. 25). During late August to October, the galls open and the nearly mature nymphs crawl out onto the needles. The nymphs transform to winged adults in a couple of days but, because they are weak fliers, many remain on the tree. The females insert their mouth parts through the bark, deposit 100 or more eggs each, and then die. These eggs hatch within 16 days and the young nymphs immediately crawl to overwintering sites. There is one generation per year. This insect is a serious pest in nurseries and Christmas tree plantations and on park and

Courtesy D. C. Allen,
SUNY, Coll. Environ. Sci. & For.

Figure 25.—Galls of the eastern spruce gall adelgid, *Adelges abietis*, on spruce.

other ornamental trees. It damages trees by reducing their vitality, detracting from their esthetic value, and weakening shoots at points of gall formation.

The **Cooley spruce gall adelgid**, *Adelges cooleyi* (Gillette), is a native pest that occurs from coast to coast in the Northern United States and throughout the range of white spruce in Canada. Its primary hosts in North America are white, blue, Sitka, and Engelmann spruces. It also has an alternate host, Douglas-fir.

The Cooley spruce gall adelgid overwinters as an immature female under bark scales near the terminal of twigs of spruce. In early spring the female develops into a stem-mother and deposits up to 350 eggs under a mass of white, cottony wax. The eggs hatch in 1 to 2 weeks, and the nymphs settle down to feed at the bases of young needles. Elongate, conelike galls (fig. 26) begin to form immediately and develop rapidly, enclosing the nymphs. Young galls are fleshy and green or purple; older ones are dry and reddish brown. They vary greatly in size, from about 25 to 75 mm in length and 12 to 18 mm in diameter. When the nymphs become mature, the galls open, allowing the nymphs to escape and crawl to the needles. Here they transform into winged adults and fly to Douglas-fir, if present. Eventually, a winged generation is produced on this host, and it returns to spruce *(271)*. Where spruce and Douglas-fir do not occur close enough together for the aphid to move back and forth from one to the other, continous generations may be produced independently on either species.

F-519584

Figure 26.—Galls of Cooley spruce gall adelgid, *Adelges cooleyi*, on blue spruce.

The Cooley spruce gall adelgid is not usually considered an important pest in the forest. However, it may be troublesome where spruce and Douglas-fir are growing close together. Ornamental spruce and young spruce trees in Christmas tree plantations are often seriously damaged by excessive numbers of unsightly galls. No galls are produced on Douglas-fir but heavy adelgid attacks on this host can cause abnormal dropping of foliage.

The **balsam woolly adelgid**, *Adelges piceae* (Ratzeburg), an introduced species first recorded in North America from Brunswick, Me., in 1908, now occurs in the Maritime Provinces, Canada, and the Northeastern States. Infestations also occur over much of Newfoundland, in the Gaspé Peninsula of Quebec, in the southern Appalachians, in the Pacific Northwest, and in British Columbia. Its hosts are balsam and Fraser firs in eastern North America. Full-grown adelgids are roughly spherical, about 1 mm long, and almost invisible to the naked eye. Because of a covering of white wax threads, however, they appear conspicuously as dots of white "wool" (fig. 27).

F-519571

Figure 27.—Infestation of the balsam woolly adelgid, *Adelges piceae*, on trunk of Fraser fir.

Clusters of amber eggs are deposited in the late spring and early summer; each egg is attached to the bark behind the female's body by a silken thread. Newly hatched crawlers form the only motile stage in the life cycle of this insect. When suitable feeding sites are found on the surface of the bark, these crawlers insert their stylets, become stationary, and turn black except for fringes of white wax plates around the edges of the body and down the dorsum. After a period of dormancy lasting from 2 to 8 weeks they develop into the second generation. Adults of this generation deposit eggs during midsummer. Hatching soon occurs and all stages are found until late fall. The winter is spent as stationary first-stage larvae. In the spring these larvae resume activity and reach maturity by the time the buds begin to swell. New adults appear by mid-April in the southern Appalachians and in early May in

the Northeast. There are two generations per year in the Northeast; in the southern Appalachians, two and occasionally three generations are produced *(13, 47)*.

The balsam woolly adelgid feeds at any point on the tree where it can reach the parenchyma of the cortex with its mouth parts. During feeding, it introduces an irritating salivary substance into the tissues that causes an abnormal multiplication of cells and excessive growth in the vicinity of the point of attack. Infested twigs and small branches become swollen and distorted. Swellings are particularly noticeable at nodes and around buds. Branchlets may thicken, twist irregularly, and bend down at the ends. The main stem tapers rapidly toward the top. The tip becomes bent or flattened and is usually killed. This results in a condition commonly known as "gout." The wood of infested trees becomes hard and brittle, and its surface is usually marked with dark, reddish-brown blotches. This type of wood, which resembles "compression" wood, is produced in greatest amount on moderately infested fast-growing trees. Trees suffering from heavy stem attack may be killed in 2 or 3 years (fig. 28).

The balsam woolly adelgid is subject to a considerable amount of control by low winter temperatures, especially in the northern portions of its range. Tree resistance is also an important control factor, some trees being less favorable for multiplication of the insect than others. So far, no insect parasites of the adelgid have been found. Quite a large number of predators have been recorded and additional ones have been imported to supplement native species. However, adelgid populations expand so rapidly and some firs are so sensitive to attack that predators effect little control before trees are damaged irreversibly.

In a few situations, the spread of infestations may be checked by the prompt salvage of infested stands during the winter. Short rotation and cutting cycles, combined with silvicultural methods of reducing the balsam fir content of stands, have helped in reducing infestations in New Brunswick *(50)*.

Adelges laricis Vallot, an introduced species, occurs in southern Canada and south and east in the Eastern States to Washington, D.C., and the Lake States. Its hosts are recorded as European larch, tamarack, and spruces, principally red and black. Infestations on larch appear as white woolly masses on the needles and as clusters of adelgids at the bases of needles. Infestations on spruce may be recognized by the presence of small pineapple-shaped galls at the tips of new growth. A related species, *A. lariciatus* (Patch), occurs on larch and various species of spruce *(272)*. It produces galls similar to those produced by the eastern spruce gall adelgid.

The **pine bark adelgid**, *Pineus strobi* (Hartig), a widely distributed species in Europe and North America, occurs over most of the United States wherever white pines grow. It is small, dark, and covered with flocculent wax. Infestations may be recognized by the presence of spots and patches of white cottony material on the smooth bark of the trunks and limbs (fig. 29), at the bases of needles on twigs, or on buds. Feeding, though, is limited to the bark. The trunks of heavily infested trees often appear as if whitewashed.

Eggs are laid in the spring by overwintering females, and the eggs hatch into both winged and wingless females. Winged forms, though, are produced less consistently than wingless ones. The wingless forms remain on the pine host and reproduce repeatedly. Five generations per year have been recorded as far north as the Lake States *(1010)*. Although winged forms may fly to spruce and lay fertile eggs, both adults and offspring eventually die.

Trees in parks and recreational areas, ornamentals, and small nursery stock sometimes become heavily infested by the pine bark adelgid. However, it is

doubtful that such attacks produce permanent damage if the trees are healthy. Similarly, mature trees repeatedly infested in the forest or in eastern white pine plantations evidently suffer no serious harm.

F-519567

Figure 28.—Fraser fir killed by the balsam woolly adelgid, *Adelges piceae*.

Courtesy Conn. Agric. Exp. Stn.

Figure 29.—Infestation of the pine bark adelgid, *Pineus strobi*, on the trunk of pine.

The **pine leaf adelgid**, *P. pinifoliae* (Fitch), occurs in both the Eastern and Western United States. Its range in the East coincides with that of its primary hosts, red and black spruces, wherever they grow close to its alternate host, white pine. The offspring produced by adults migrating from spruce provide the easiest means of diagnosing an outbreak on pine. The small, scalelike "larvae" are fringed with white hair and often become numerous enough to cover a shoot completely.

The life cycle takes 2 years to complete. During part of this time, including the first winter, infestations are found entirely on spruce; during the remaining time, including the second winter, they are found on pine *(752)*.

Infestations on spruce result in the production of terminal compact galls that have the appearance of true cones consisting of many chambers, each containing a single adelgid. These galls are of minor importance except on ornamentals, where they may be undesirable. Heavily infested white pines, especially young pines in plantations, may be severely injured. The early symptoms are drooping branches that turn red by summer, and die. In heavy infestations, growth is reduced and occasionally trees up to 12 cm in diameter are killed. Some outbreaks spread over large areas before subsiding.

Pineus floccus (Patch), the **red spruce adelgid**, feeds on red and black spruces and eastern white pine, spending 1 year of its 2-year life cycle on each. It produces loose, terminal galls on spruce. On pine, its effects are similar to those caused by the pine leaf adelgid. Heavy infestations on spruce may kill the tips of branches or they may cause an overproduction of laterals, which leads to bushy, deformed trees. Damage to pine is usually not serious.

Pineus similis (Gillette), the **spruce gall adelgid**, produces terminal ragged galls on various spruces but appears to prefer white spruce in the East. No alternate hosts have been found for this species. The galls are shorter and thicker than those produced by the Cooley spruce gall adelgid and the chambers inside are intercommunicating. Small white spruce growing in the open in Canada has been severely infested. *P. coloradensis* (Gillette) has been observed feeding on the needles of red and pitch pines in Connecticut, although its host range is much wider *(774)*. Laboratory studies indicate that red pine seedlings readily succumb to heavy infestations of this species.

Family Phylloxeridae
Phylloxeras

Members of this family resemble those of the family Adelgidae except that winged forms have fewer antennal segments and all species feed exclusively on dicotyledonous plants.

The genus *Phylloxera* contains several species that produce galls on hickories and pecan. These aphids do not produce waxy threads as do many other members of the family, but some of them may be covered with a waxy powder. Their galls vary from small disklike or buttonlike swellings, with central openings guarded by plantlike hairs or processes, to large, hollow, globelike structures up to 18 mm in diameter.

Phylloxera caryaecaulis (Fitch), the **hickory gall phylloxera**, is a common species that produces almost spherical galls, 16 to 18 mm in diameter, on the twigs and leaf stems of hickory. The galls are green when first formed; later, after the phylloxeras vacate them, they turn brown or black. The **pecan phylloxera**, *P. devastatrix* Pergande, and the **pecan leaf phylloxera**, *P. notabilis* Pergande, produce galls on pecan and other hickories. *P. rileyi* Riley is found on white and post oaks, and *P. nyssae* Pergande infests blackgum.

Family Aleyrodidae
Whiteflies

Members of this family are very small mothlike insects, usually less than 2 or 3 mm in length. The adults all have four wings each. The wings, covered with a powdery wax, are whitish in appearance. The larvae are very small and scalelike; they are usually found surrounded or covered with a waxy secretion on the undersides of the leaves of the host plant. Whiteflies are most abundant in tropical and subtropical regions, but a few species have been recorded as far north as New England.

The **mulberry whitefly**, *Tetraleurodes mori* (Quaintance), feeds on mulberry, dogwood, azalea, hackberry, holly, mountain-laurel, basswood, maple, and sycamore. The larvae are less than 1 mm long, jet black, and ringed around with a white fringe. Adults are active from June to September. The **rhododendron whitefly**, *Dialeurodes chittendeni* Laing, an introduced species, feeds on rhododendron. The adult is pale yellow; the larvae and pupae are greenish yellow. Infested leaves have a yellow, mottled appearance, and their margins curl. The **citrus whitefly**, *D. citri* (Ashmead), feeds on chinaberry and on crapemyrtle in Florida. The **azalea whitefly**, *Pealius azaleae* (Baker & Moles), feeds on azalea as far north as Rhode Island and Ohio, and sometimes causes severe defoliation. *Aleurochiton forbesii* (Ashmead) feeds on maple.

Superfamily Coccodidea
Scale Insects

Scale insects are among the most destructive pests of shade trees, ornamentals, and greenhouse vegetation, and may cause serious damage to forest growth. Injury apparently results from the ingestion of large amounts of plant sap and from the production of honeydew, which serves as a substrate for the growth of sooty mold. As with aphid honeydew, many beneficial species feed on this material. Plant deformation and toxin injury are produced by a few scale insects.

Adult female scales lack wings, may have legs, and are saclike with no definite head, thorax, or abdomen. Adult males are more insectlike in appearance, usually with one pair of wings, one pair of "halteres," long legs, and a definite head, thorax, and abdomen. Adult males are rarely collected because they are small and normally live only a day or two. Most scale insects produce a waxy secretion that covers the body either as a shieldlike structure separate from the body or as a coating on the body surface. The wax varies from a thin, translucent sheet to a thick, wet mass or to a powdery bloomlike secretion.

Some scale insects are host-specific, but others feed on a wide variety of plants. Because of the small size and cryptic appearance of most of these insects, many pest species have been distributed inadvertently by commerce as plant contaminants.

Natural dispersal is primarily by highly mobile windblown crawlers or first instars, but dispersal by birds and mammals has also been suggested. In most instances, instars other than the crawler are relatively sessile and are unimportant in natural dispersal.

The life stage most susceptible to chemical control is the first instar, apparently because during part of this stage there is little or no protective wax covering on the insects. Attempts to control other life stages are frequently unsuccessful. Therefore, for effective chemical control, it is important that information on the life cycle be available so that insecticidal spray applications coincide with crawler emergence.

It is important to remember that egg hatch may occur at different times in different areas of the United States. Also, some species have short egg-hatch periods, while others have hatch periods that extend over entire growing seasons.

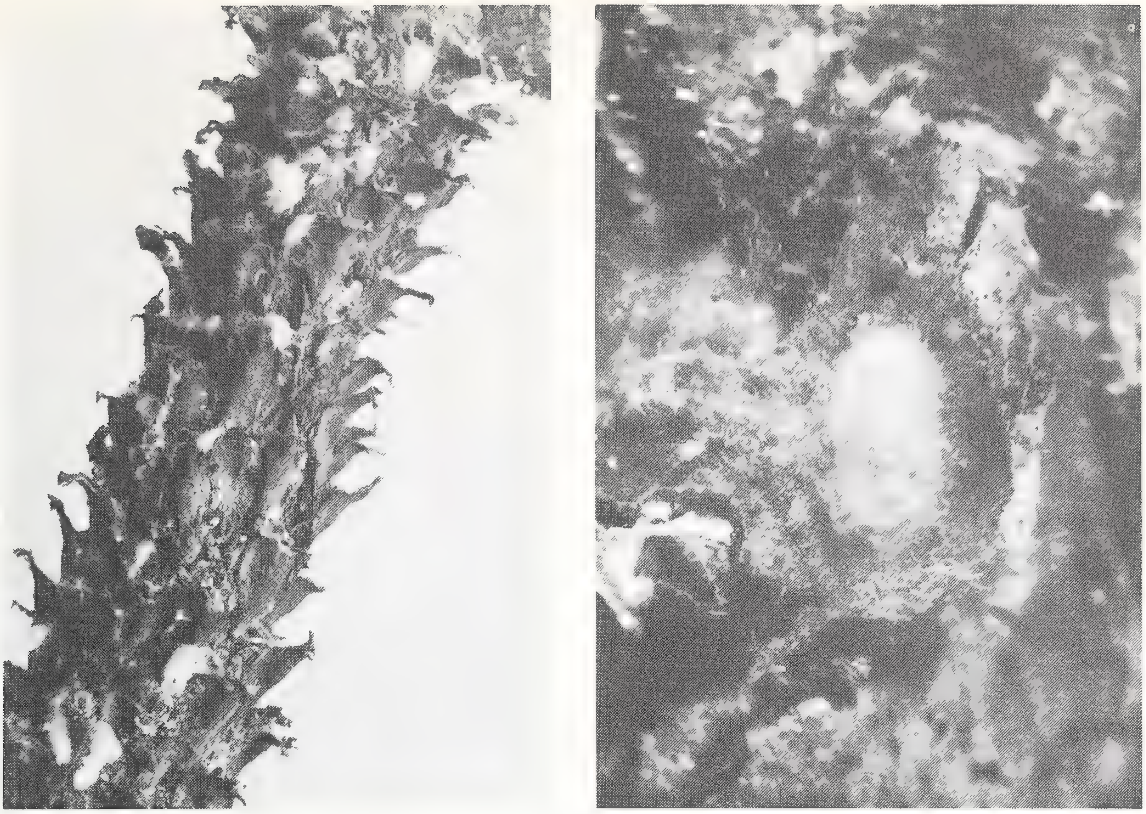
Natural enemies are frequently effective control agents of scale insects. In forests, natural enemies are commonly encountered components of the scale insect ecosystem.

Family Margarodidae
Margarodid Scales

Margarodids are primarily tropical or subtropical in distribution, although several groups occur in temperate areas. The family can be divided into two groups—i.e., the cyst-formers and the noncyst-formers. The cyst-formers produce a heavily sclerotized, legless stage that develops between the legged crawler and the adult. In at least one species, this so-called cyst or resting stage is highly resistant to environmental restraints and has been stored alive for 17 years *(834)*. Noncyst-formers are generally similar in appearance throughout their development and do not form a special "resting" stage. Margarodids may occur anywhere on the host from the roots to the foliage; many species occur under the bark of their hosts. The family Margarodidae contains 42 species of 11 genera in the United States. A comprehensive study of this family is available *(887)*.

The **red pine scale**, *Matsucoccus resinosae* Bean & Godwin, was first reported in western Connecticut on red pine in 1946. It has now spread northward and eastward in Connecticut and is found in southeastern New York and northern New Jersey, and an infestation was recently discovered in Morris Arboretum, Philadelphia, Pa. *(1163)*. The species apparently is expanding its distribution at a rate of 1 to 3 km per year *(771)*. Red pine scale occurs only on pines of the sylvestris subsection of *Pinus*, which, in North America, is represented by one native species—red pine (fig. 30). The subsection is diverse in Europe and Asia where over 17 species are reported. This Eurasian diversity has caused many to suggest that red pine scale may not be native to the United States but rather is introduced from Eurasia *(17)*. This idea is supported by its distribution in the United States, which is entirely outside the natural range of red pine. Red pine scale has been reported on red, Chinese, Japanese red, and Japanese black pines, and is restricted to plantations, nurseries, and ornamental plantings.

The species has two generations per year and overwinters as a first-instar crawler under or in cracks of the bark *(79)*. In April the cyst stage appears, and by the end of the month the waxy sacks of developing males are obvious on the undersides of branches. In May and June, adults and eggs are present. Hatching occurs in about 15 days, and crawlers of the summer generation reach the adult stage in August. In late August the overwintering first instars begin to appear. The red pine scale is the most destructive insect pest of red pine in the Northeast. Thousands of young to fully mature trees have been killed. The foliage of infested trees generally changes progressively from olive green to yellow and then to red. The bark appears swollen and cracked, and an area of dead tissue is present beneath each feeding scale. It has been suggested that the death of infested trees might be partially caused by a toxin produced by the scale *(986)*. Long-range dispersal is principally by wind *(772)*. No effective natural enemies are known in the United States but biological control exploration is underway in the Orient. In one experiment, exposure to $-23°$ C for two 4-hour periods was lethal to 99 percent of the overwintering crawlers *(531)*, but this experiment has never been duplicated. Chemical control is possible, but this is practical only on ornamental trees.



Courtesy Conn. Agric. Exp. Stn.

Figure 30.—Masses of male cocoons and a closeup of the red pine scale, *Matsucoccus resinosae*.

Matsucoccus gallicolus Morrison, the **pine twig gall scale**, is apparently a native species. It has been recorded in 16 States from New Hampshire to Florida and west to Missouri. It occurs on loblolly, pitch, ponderosa, red, shortleaf, spruce, Table Mountain, and Virginia pines.

The pine twig gall scale has one generation per year and normally overwinters as an egg. Hatching occurs when the new year's growth is 2.5 to 7.5 cm long *(149)*. The crawlers migrate from the bark to the new green growth where they settle. As feeding progresses, cells beneath the scale body collapse, eventually leaving the crawler in a small depression. Molting occurs, and the first-instar crawler transforms into a cyst. The host plant grows around the cyst until the scale is completely enclosed except for a small hole that apparently is kept open by the trapped shed skin of the crawler. By the end of July, the cyst molts to the adult female stage; she squeezes through the hole in the gall, migrates to the trunk or a main branch, and lays the overwintering eggs under the bark. Adult males have not been reported.

The pine twig gall scale is an important pest of pitch pine and may kill mature trees, although it is most detrimental to young trees *(959)*. This scale frequently kills limbs and is particularly injurious to ornamental plantings.

Matsucoccus alabamae Morrison, the **Alabama pine scale**, is reported on the bark of pines in Alabama, but no major damage has been attributed to this species. *M. macrocicatrices* Richards, the **Canadian pine scale**, occurs in southeastern Canada and New Hampshire where it is found on eastern white pine. The scale is unique among the pine scales in that it is associated with the fungus *Septobasidium pinicola* Snell in an apparent mutualistic relationship.

Canadian pine scale has one generation every 2 years and overwinters in the cyst stage in fungal mats *(1255)*. Eggs are laid in cracks of the bark early in the year. Crawlers migrate to the edges of fungal mats where they feed and molt to the cyst stage. The cyst remains in the fungal mat for nearly 2 years before transforming to

the adult female early in the third spring. Males have been reported *(1025)*, but apparently are rare. No major plant damage is attributed to this scale, although minor host deformation at feeding sites is sometimes apparent when fungal mats are removed.

Xylococculus betulae (Pergande), the **birch margarodid**, apparently is a native species. It occurs from eastern Canada to Tennessee and west to Ohio on birch, beech, and occasionally on willow and maple. Adult females are bright orange, about 4 mm long, and are covered with white wax.

The length of a generation is unknown, but a single cycle probably requires more than 1 year. The crawler settles in cracks or lenticles on the trunk of the host, produces a waxy cell, and eventually is covered by the surrounding bark. The crawler molts to the cyst, which produces a thin, waxy tube that protrudes up to 5 cm above the bark surface and acts as a passage for honeydew *(620)*. The adult female has legs but normally remains inside the shed skin of the cyst. A hole is formed near the apex of the cyst-shed skin through which the male mates and the crawlers emerge to the host surface. The birch margarodid is reported to kill young birch trees under some circumstances, although damage is normally restricted to localized necrotic areas on the bark *(1079)*. On beech this scale insect normally does not kill the tree but causes roughened or swollen spots on the trunk that eventually dry and form large cracked areas. Damage is usually restricted to narrow longitudinal strips that start at old branch stubs.

Neosteingelia texana Morrison is native to North America. It occurs in Alabama, Florida, Georgia, Pennsylvania, South Carolina, Tennessee, Texas, and Virginia. It is most often collected on pecan and hickory, but material is at hand from hackberry, sugar maple, and sweetgum. The species occurs in native and ornamental habitats. Adult females and males are unusually large for a scale and are reddish brown.

This margarodid probably requires more than 1 year for a generation in Virginia,[4] and at least part of its populations overwinter as eggs. Eggs are laid under the bark, and they hatch in early spring. Adults mate on the bark in late September or early October. Information is not available on its economic importance or natural enemies.

Family Ortheziidae
Ensign Scales

This family is a homogenous group that occurs predominantly in the New World, although a limited number of species is known from New Zealand, Europe, the Soviet Union, Japan, and Africa. Ensign scales are easily recognized in the field by the sharply defined, platelike, waxy tufts over much of their bodies. The ovisac is constructed of similar wax and is attached to the venter of the scale. This allows the female to move on the host even while ovipositing. Apparently there are four instars in the female and five in the male. Males are generally rare. The family contains 32 species in 4 genera in the United States *(886, 888)*.

In eastern forests several members of this family may be encountered. *Orthezia tillandsiae* Morrison, the **Spanish moss orthezia**, occurs on Spanish moss in Florida, Georgia, Louisiana, and Virginia, and probably in all areas of the United States where Spanish moss occurs naturally. *O. pseudinsignis* Morrison occurs on many hosts, including walnut, in Louisiana.

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[4] Kosztarab, M. (personal communication). Virginia Polytechnic Institute and State University, Blacksburg, Va.

Family Pseudococcidae
Mealybugs

This is a large and diverse family of scale insects that is cosmopolitan in distribution. Mealybugs are recognized in the field by the filaments around the body margin and a covering of mealy wax. In general there are four female instars and five male instars. The family contains 281 species in 45 genera in the United States. Detailed publications are available for this group *(409, 411, 796)*.

Dysmicoccus wistariae (Green), the **taxus mealybug**, is apparently an introduced species. In the United States it occurs in 15 Northeastern and Midwestern States from Maine to Maryland and west to Missouri. It is most abundant on yew but is also reported on maple, rhododendron, dogwood, and *Prunus* spp. The taxus mealybug normally occurs in ornamental plantings. Adult females are covered by a white wax except on the dorsum, where four naked areas allow the red body pigments to show through as longitudinal lines. The margin of the body is adorned with 15 to 17 pairs of waxy filaments; the posterior pair is the longest and is about one-fourth the length of the body. A small, filamentous ovisac is sometimes constructed beneath the posterior part of the abdomen.

The taxus mealybug has one generation per year in Connecticut *(1068)* and parts of New York, and two or three in Massachusetts, New Jersey *(517)*, and southern areas of New York. The species overwinters in the first instar in cracks in the bark; males are common. Eggs apparently hatch inside the body of the female. Damage is reported on yew where heavily infested plants have sparse foliage, turn yellow, and are stunted and covered with honeydew and sooty mold *(1268)*. Heavy infestations can kill young plants.

The **striped mealybug**, *Ferrisia virgata* (Cockerell), is probably native to the New World. In the United States it occurs in 23 States from New York to Florida west to Louisiana and Missouri; it is also known in several Western States. The striped mealybug is polyphagous; some of its eastern hosts are maple, azalea, boxwood, catalpa, dogwood, hawthorn, holly, magnolia, apple, mulberry, and persea. It is found in natural habitats and ornamental plantings. The gray body of the adult female is covered with a white wax except on the dorsum, where two longitudinal areas are without wax and form stripes. There is a single pair of caudal filaments extending about one-half the length of the body. Many long, thin, crystalline rods are present on the dorsum. The adult female produces a small waxy pad beneath the abdomen on which the eggs are laid. Males may be present.

The striped mealybug has two generations per year in Maryland on azaleas, and overwinters as a second or third instar *(568)*. Feeding begins in early April in leaf axils or at the base of flower buds, and adults appear in early May. Eggs are laid and hatch during the second week of June. Adults of the summer generation are present in late July, and first instars of the winter generation first appear in early August. Damage may occur on most hosts of the striped mealybug. Many natural enemies are reported for this pest, including chalcidoid wasps, lady beetles, flower flies, and gall midges.

The **apple mealybug**, *Phenacoccus aceris* (Signoret), is apparently an introduced species from Europe. In the United States it occurs in five States from Maine south to Massachusetts in the East. This species is polyphagous, although it prefers rosaceous hosts such as apple and hawthorn. The species is principally a pest of ornamentals, although it is found occasionally in natural habitats. The green body of the adult female is covered by white wax. The body margin has 16 to 18 pairs of

lateral filaments; the caudal pair is about one-eighth as long as the body. An ovisac is produced that encloses all but the anterior portion of the adult female.

The apple mealybug has one generation per year and overwinters as a second instar in crevices in the bark. In early spring, the second instars migrate to the leaves or new growth of the stems. In late spring and early summer, adults appear, mating takes place, and egg laying begins. First instars appear in July and feed primarily on the leaves. Second instars migrate from the leaves to the bark in the fall. The apple mealybug is an economic pest in apple orchards in Maine, Nova Scotia, and British Columbia, and is occasionally a pest of ornamentals such as maple, basswood, and cotoneaster. In many areas this mealybug is held to low populations by the small wasp *Allotropa utilis* Muesebeck. Other natural enemies include chalcidoid wasps and lady beetles.

Phenacoccus acericola King, the **maple mealybug** or **maple phenacoccus**, is probably an introduced species. In the United States it occurs in 16 States from Maine to Tennessee and west to Illinois. The preferred host is sugar maple, but it is also reported on other species of maple and on buckeye, basswood, and hornbeam. The species is normally a pest in ornamental plantings, but is also present in natural habitats. The adult female is yellow and is lightly dusted with a flocculent white wax. The body margin has 16 to 18 pairs of broad, waxy filaments which are less than one-fourth the length of the body. An ovisac encloses all but the anterior end of the adult female.

In Ohio, the maple mealybug has two or three generations per year on sugar maple and overwinters in bark crevices as immatures *(605)*. The overwintering immatures migrate to leaves of the host and feed in the early spring. In June the adult females migrate to the bark and mate. The adult females return to the leaves, produce a large ovisac, and lay more than 500 eggs. The ovisacs generally are produced on the underside of the leaves near the primary veins. Damage caused by the maple mealybug principally detracts from the appearance of the host. Several chalcidoid wasp parasites and lady beetle predators have been found associated with the maple mealybug.

Phenacoccus dearnessi King, the **twocirculi mealybug**, is of uncertain origin; it may be a native species. In the East it occurs in Illinois, Indiana, Iowa, Kansas, Maryland, Missouri, New York, Ohio, Pennsylvania, and Wisconsin; it is also reported in five Western States. The species is restricted to rosaceous hosts: serviceberry, cotoneaster, hawthorn, quince, and *Prunus* spp. It is a pest in ornamental plantings, although it is found also in natural habitats. The adult female is red and is covered by a thin layer of white wax. The lateral filaments are short and inconspicuous or are absent. The ovisac may be absent or restricted to the posterior part of the venter. Males are abundant.

The twocirculi mealybug has one generation per year and overwinters as second instars in crevices in the bark. In the spring the females move and begin feeding in the crotches of twigs or at the bases of bud scales. Adult females produce living young or eggs that hatch within minutes after being laid. First instars settle on the leaves and begin feeding. In the summer the crawlers migrate to cracks in the bark and go through a summer diapause period. During early fall the crawlers return to the leaves, feed, and develop into second instars. In late fall the second instars move to the overwintering sites. Heavy populations of the twocirculi mealybug cause accumulations of large quantities of honeydew and sooty mold and give the host plants an unsightly appearance. Large infestations may cause early leaf drop. Natural enemies are not reported for this pest. Normally, chemical control is fairly successful.

Spilococcus juniperi (Ehrhorn), the **juniper mealybug**, is a native species. In the East and Midwest it occurs in Florida, Indiana, Iowa, Kansas, and Nebraska; it is also reported from six Western States. The species is restricted to juniper and seems to prefer redcedar and oneseed juniper. The juniper mealybug is found in native habitats and ornamental plantings. The adult female is dark purple, is covered with a smooth gray wax, and has two bare areas forming longitudinal stripes on the dorsal part of the thorax and abdomen. The body margin has several short, partially coalesced filaments. The ovisac encloses the venter of the female, forming a nestlike structure.

The juniper mealybug's life history is unknown except that it feeds on the foliage of the host and lays eggs. This mealybug is a serious pest of ornamental plantings of redcedar and oneseed juniper in Kansas, Oklahoma, Texas, and Indiana. The foliage of heavily infested trees turns brown and drops, beginning on the lower and inner branches of the host. Entire trees are sometimes defoliated. Two chalcidoid wasps have been reared from this mealybug.

The **Comstock mealybug**, *Pseudococcus comstocki* (Kuwana), probably was introduced from the Orient. In the Eastern United States it occurs from New Hampshire to Florida and west to Missouri; it has also been reported from two Western States. This mealybug is polyphagous and is frequently collected on catalpa, mulberry, and yew. Other eastern forest hosts are holly, buckeye, maple, and poplar. The species is normally restricted to ornamental plantings. The adult female is reddish brown and is covered with a white wax in which two dorsal bare areas form longitudinal stripes. The body margin has approximately 17 pairs of long filaments; the caudal pairs are longest and are about one-third to three-fourths the length of the body. The filamentous ovisac normally covers all of the adult female.

The Comstock mealybug has three generations per year, and in Virginia *(604)* and California *(64)* it overwinters as an egg in the ovisac. Adult females usually move from the feeding areas and oviposit in protected areas on the bark. Ovisacs contain 200 to 300 eggs; with the exception of overwintering periods, eggs hatch 1 to 2 weeks after being laid. Males are common and apparently are required for reproduction. This mealybug has many natural enemies, including chalcidoid wasps, platygasterid wasps, lady beetles, green and brown lacewings, and a fly. Two parasites that have been effective biological control agents are the wasps *Pseudaphycus malinus* Gahan and *Allotropa convexifrons* Muesebeck.

The **grape mealybug**, *Pseudococcus maritimus* (Ehrhorn), is a native species. Because of confusion surrounding the proper identity of *P. maritimus* and the closely related species *P. obscurus* Essig, much of the literature about *P. maritimus* actually pertains to *P. obscurus*. In the United States the grape mealybug is reported in 21 States; in the East it occurs in 18 States from New York to Florida and west to Missouri. The species is polyphagous, but in the East it often causes damage to yew and grape. It occurs in natural habitats and ornamental plantings. The yellow to orange body of the adult female is covered with a gray wax. The margin of the body has 17 pairs of thin lateral filaments; the caudal pair is about one-fourth the length of the body. An ovisac is produced that encloses all but the head of the mealybug.

The grape mealybug has two generations per year in central California *(812)* and Ohio *(914)* and overwinters as first instars in the ovisac in cracks in the bark. In early spring the first instars move to the foliage or flower buds of the host and feed. In early summer adult females move to the bark of the host and oviposit. The eggs hatch in July, and the first instars feed on the green portions of the stems. In late

summer the second generation females mature, move to the bark of the host, and lay eggs. The eggs hatch and the first instars remain in the ovisac for the winter. Occasionally, second and third instars may overwinter. Males are known. Many natural enemies of this mealybug are reported, including chalcidoid wasps, several lacewings, and five lady beetles. Chemical control apparently is difficult.

Many other mealybug species may be encountered in eastern forests. Because of this diversity, it is impossible to give detailed information about all species that might be found. However, additional species include *Dysmicoccus morrisoni* (Hollinger) on pecan and hickory in Alabama, Georgia, Louisiana, Mississippi, Missouri, New Jersey, and New York; *D. obesus* (Lobdell) on pine in Mississippi; *D. difficilis* (Lobdell) on blackgum, ash, and willow in Louisiana, Maryland, Mississippi, South Carolina, and Virginia; *Oracella acuta* (Lobdell) on pine, particularly loblolly, in Florida, Georgia, Louisiana, Maryland, Mississippi, North Carolina, South Carolina, Texas, and Virginia; and *Peliococcus serratus* (Ferris) on beech in Connecticut, District of Columbia, Massachusetts, Maryland, New Jersey, New Hampshire, New York, Ohio, Pennsylvania, and Virginia.

Family Coccidae
Soft Scales

Soft scales are common pests of ornamentals throughout most of the world, although they generally are more abundant in tropical and subtropical areas. These scales are generally without an obvious waxy covering, although members of a few genera form conspicuous ovisacs or are covered with an ornate, amorphous wax. There are three or four instars in females and five in males. The family contains 90 species in 22 genera in the United States. Comprehensive studies of this family in the United States have been published *(1154, 1310)*.

Ceroplastes ceriferus (F.), the **Indian** or **Japanese wax scale**, was apparently introduced from the Orient. In the United States it occurs in 16 States from New York to Florida and west to Texas, although it probably does not survive out of doors north of Delaware. The host range is extensive, including such plants as Japanese and Chinese hollies, euonymus, camellia, and eastern hemlock. The Indian wax scale is normally found in ornamental plantings. Adult females are covered by a white amorphous wax that is hemispherical in shape and has an anteriorly projecting horn. The body of the adult female is pinkish purple to dark reddish-brown.

The Indian wax scale has one generation per year in Virginia and Maryland *(1105)*; it is possible that more than one generation occurs in southern areas. In Maryland the species overwinters as adult females. In late spring the adults begin to lay eggs that hatch in about 3 weeks; a single female may lay more than 1,000 eggs. First instars settle on the stems of the host and develop into adult females by late summer. Males are uncommon. This wax scale does not usually kill its host but frequently gives the heavily infested plant a scraggly appearance and covers the host with honeydew, which eventually is contaminated with black sooty mold *(486)*. Natural enemies include several species of chalcids and a pyralid moth.

Other less common species of *Ceroplastes* that might be encountered in the East are the **barnacle scale**, *C. cirripediformis* Comstock, which occurs on citrus trees and gardenia, and the **Florida wax scale**, *C. floridensis* Comstock, which is found on pine, hemlock, and maple. Both species occur in the warm Southern States on many native and ornamental trees.

The **calico scale**, *Eulecanium (= Lecanium) cerasorum* (Cockerell), is probably native to the Orient. In the Eastern United States it occurs in Delaware, District of

Columbia, Maryland, New Jersey, New York, Pennsylvania, Rhode Island, and Virginia. The host range is extensive, including many common ornamentals; in Maryland it is often found on dogwood, maple, the ornamental star magnolia, and ornamental fruit trees, and is rarely reported in natural habitats. The mature calico scale is globular and has irregular white patches on a dark-brown background. As the scale ages, the white patches disappear.

The calico scale in Maryland has one generation per year and overwinters as second instars on the bark of the host.[5] In early spring, second instars begin to feed, molt twice, and develop into globular adults. In late spring and early summer, eggs are laid. During June, first instars appear on the undersides of leaves. In late summer and early fall, the crawlers molt to second instars and move from the leaves to the stems and trunks where they overwinter. Adult males have not been observed in Maryland. The calico scale normally does not kill trees, but produces large amounts of honeydew, giving the host an unsightly appearance. Two chalcidoid wasps have been reported associated with this scale.

Eulecanium (= Lecanium) caryae (Fitch), the **large hickory lecanium**, is known primarily in the Northern States from Maine to Virginia and west to Kansas; the species is also reported from Mississippi. The large hickory lecanium is polyphagous, being found on most trees in the eastern forests, including hickory, birch, elm, beech, walnut, oak, and mulberry. This scale is found in native habitats and ornamental plantings. Adult females are unusually large, sometimes reaching 15 mm in length. The body is normally flat and uniformly brown or orange-brown and is covered with a white bloom.

The large hickory lecanium has one generation per year in Michigan *(1241)* and overwinters as immatures. Adult females lay over 100 eggs. Hatching occurs in the summer and first instars feed on the undersides of leaves. In late summer the immatures move from the leaves to the stems, where they overwinter *(1310)*. On elm this species tends to infest medium-size branches.[6] The large hickory lecanium is normally not an economic pest but is a common inhabitant of eastern forests. Three species of chalcidoid wasps are reported as associated with this scale insect.

The **terrapin scale**, *Mesolecanium (= Lecanium) nigrofasciatum* (Pergande), is probably native to North America. In the Eastern United States, it is known from every State except New Hampshire and Vermont. The species is polyphagous, and is commonly found on maple, sycamore, and fruit trees in natural habitats and ornamental plantings. Fully developed adult females are hemispherical and are dark reddish-brown with many radiating bands extending from the center of the dorsum to the raised edge of the body.

In Virginia, the terrapin scale has one generation per year and overwinters as adult females *(1310)*. In early spring, first instars are produced and remain under the body of the adult for 1 to 3 days before moving to the undersides of leaves. In about 18 days, first instars molt to second instars that molt to adult females in a similar period of time. In the fall, adult females move from leaves to twigs where they overwinter. Males are usually common in early summer. The terrapin scale has been reported as a serious pest in fruit tree orchards. It is commonly encountered on forest and shade trees and produces large amounts of honeydew. Over 30 natural enemies have been recorded as associated with this scale, including chalcidoid wasps, lady beetles, green and brown lacewings, a pyralid moth, and fungi.

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[5] Stoetzel, M. B. (personal communication). USDA ARS Syst. Entomol. Lab., Beltsville, Md.

[6] Weidhaas, J. A. (personal communication). Virginia Polytechnic Institute and State University, Blacksburg, Va.

The **magnolia scale**, *Neolecanium cornuparvum* (Thro), is probably native to North America. The species occurs in at least 15 Eastern States from New York to Florida and west to Wisconsin. This scale is restricted to species of magnolia and is found in natural habitats and ornamental plantings (fig. 31). Newly mature adult females are covered with a white bloom that is rapidly lost with age. Older females are brown or yellow, are convex, and are very large, attaining a length of 12 mm.

Courtesy Conn. Agric. Exp. Stn.

Figure 31.—The magnolia scale, *Neolecanium cornuparvum*, on magnolia.

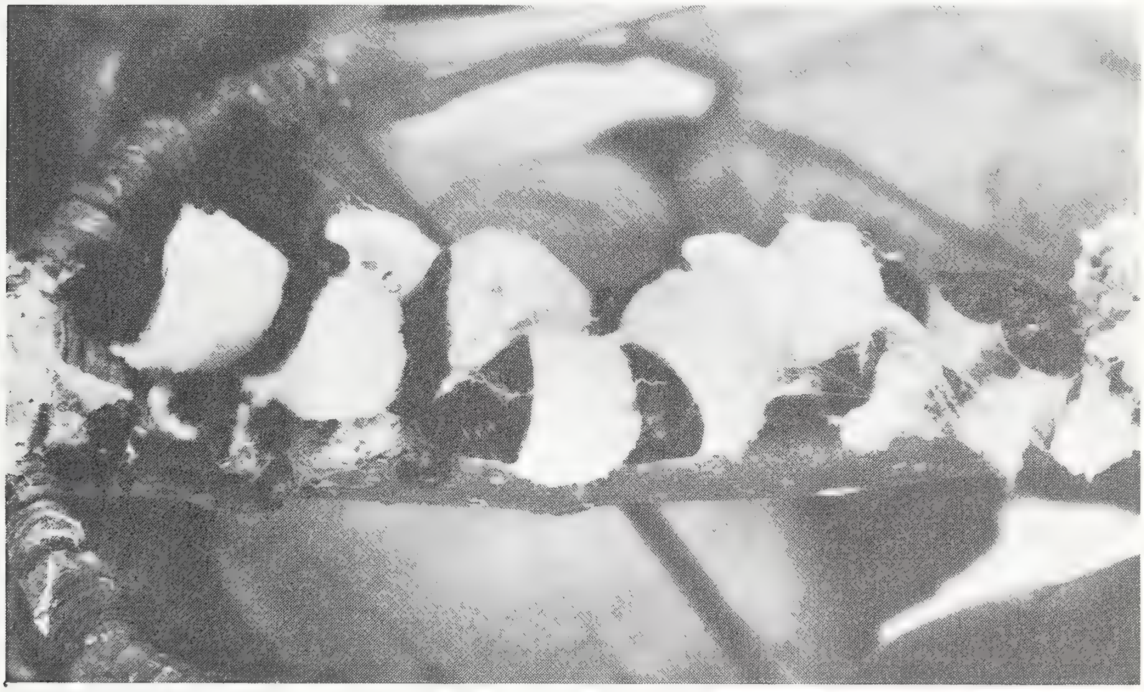
The magnolia scale has one generation per year in New York, Connecticut, and Virginia, and overwinters as first instars on 1- or 2-year-old growth. First instars begin developing in early spring and after at least two molts become adult females in early August. First instars are born as nymphs in late summer and fall. Heavy infestations of the magnolia scale can kill branches or entire trees. Large amounts of honeydew may cover the host. The only natural enemy reported for this scale insect is a lady beetle.

The **European fruit lecanium**, *Parthenolecanium (= Lecanium) corni* (Bouché), is a common cosmopolitan pest. Contrary to general opinion, this pest is apparently indigenous to North America, not Europe *(426)*. The European fruit lecanium occurs throughout the United States on many hosts in both natural and ornamental habitats. Proper identification of the species is difficult because its morphology is greatly influenced by the host *(363)*. Until biological studies are undertaken, it is impossible to sort out host-induced variations from differences characterizing separate species. The **oak lecanium**, *P. (= Lecanium) quercifex* (Fitch), and the **Fletcher scale,** *P. (= Lecanium) fletcheri* (Cockerell), are frequently impossible to separate from *P. corni* on the basis of microscopic features. *P. quercifex* is reported from oaks and *P. fletcheri* from juniper, northern white-cedar, and yew. The color patterns and body shape of the European fruit lecanium vary according to the host. Newly formed adult females are flattened and have a mottled appearance, but as they mature they become more hemispherical and turn a uniform brown.

The European fruit lecanium normally has one generation per year and overwinters as second instars. A rapid second generation has been recorded for a few populations on some hosts *(192)*. In Pennsylvania a second generation has been

reported on peach *(28)*. In late spring, from 50 to more than 2,000 white eggs are laid beneath the body of the adult female. The number of eggs is generally proportional to the size of the adult female. In early summer, eggs hatch and first instars move principally to the undersides of the leaves, although a few settle on the stems. In late summer or early fall, molting occurs and the resultant second instars move from the leaves to rough areas of branches, where they overwinter. In early spring, second-instar females grow rapidly, molt, and develop into adults. Males may be present or absent, apparently depending on the host or environmental conditions *(426)*. The European fruit lecanium normally does not kill trees but produces a large quantity of honeydew which, when contaminated with sooty mold, covers the plant with an unsightly black film. The species is sometimes a serious pest of plums, apricots, and other fruit trees. Over 40 natural enemies have been found associated with the European fruit lecanium, including fungi, lady beetles, and chalcidoid wasps. Some of the parasitic hymenopterans are effective control agents.

The **cottony maple scale**, *Pulvinaria innumerabilis* (Rathvon), is apparently native to North America and is known from nearly every State in the United States. This soft scale prefers maples, particularly silver maple, but is reported on a large number of important hosts, including basswood, ash, dogwood, hackberry, locust, sycamore, hawthorn, pear, oak, poplar, elm, willow, apple, peach, plum (fig. 32). The cottony maple scale is found in natural habitats and ornamental plantings. Adult females have variable color patterns but are generally reddish brown, and have a median ridge. The ovisac is one to two times longer than the adult and is produced by the raised, ventral abdomen.



Courtesy Can. For. Serv.,
Can. Dep. Environ., Sault Ste. Marie, Ont.

Figure 32.—The cottony maple scale, *Pulvinaria innumerabilis*, on twigs and leaves of soft maple.

The cottony maple scale has one generation per year *(1310)* and overwinters as mated, newly mature, adult females on the twigs and branches of the host. The literature often refers to the overwintering stage as immature females, but slide-mounted specimens collected during the winter show that the species overwinters as

adult females. In early spring, the adult females enlarge rapidly; ovisac development and egg laying begins in mid to late spring. A single female may lay 1,000 eggs. First instars begin to appear in early summer and are present until August. First instars move from the branches to the leaves where they develop into adult females in late summer and early fall. Adults mate in August and September. Before leaf drop, adult females move to the stems of the host. Heavy populations of this scale may cause dieback of branches and under extreme conditions may kill entire trees. This soft scale produces large amounts of honeydew, which frequently supports growth of sooty mold. Natural enemies include six species of chalcidoid wasps, several lady beetles, a green lacewing, a pyralid moth, and the English sparrow.

Pulvinaria acericola (Walsh & Riley), the **cottony maple leaf scale**, is apparently indigenous to North America and is common throughout the Eastern United States. The preferred host is maple, but it is also found on dogwood, persimmon, holly, blackgum, sassafras, *Prunus* spp., and andromeda. This soft scale may be found in natural habitats and ornamental plantings. The adult female is purple with a longitudinal yellow stripe down the center of the dorsum. An ovisac is produced with two or three longitudinal ribs.

The cottony maple leaf scale has one generation per year and overwinters as second instars on the stems and branches. Adults are present in spring when mating takes place. Adult females move to the leaves and form ovisacs in late spring or early summer. The adult female normally falls from the sac soon after it is completed. Each ovisac may contain nearly 2,500 eggs *(644)*, and hatching begins several weeks after the eggs are laid. First instars settle on the leaves where they molt once. In the fall the second instars move back to the twigs and branches where they overwinter. The cottony maple leaf scale normally does not cause damage, but heavy infestations may occasionally cause early leaf drop and dieback of branches. Natural enemies include seven chalcidoid wasps and a lady beetle.

Other species of *Pulvinaria* that are common in eastern forests are *P. floccifera* (Westwood), the **cottony camellia scale** or **cottony taxus scale**, known in the East from Connecticut to Florida and west to Missouri on many hosts, including camellia, Chinese holly, and yew. The cottony camellia scale is yellow to light brown with a dark body margin and has a life cycle similar to that of the cottony maple leaf scale. It can be an important pest of ornamentals.

Pseudophilippia quaintancii Cockerell, the **woolly pine scale**, is indigenous to the United States where it occurs on several pine species including Swiss mountain, loblolly, longleaf, Table Mountain, and pitch pines. This soft scale is reported from New Jersey to Florida and west to Louisiana and is restricted primarily to natural habitats. The adult female is elongate oval, yellow, light brown, or greenish yellow, and is covered with a characteristic white, cottony, waxy secretion. The biology of this species has not been studied. The woolly pine scale occasionally may be abundant enough to cause stunting of growth *(1012)*.

The **spruce bud scale**, *Physokermes piceae* (Schrank), was apparently introduced into North America. It is known in Indiana, Massachusetts, Maine, Maryland, Minnesota, Missouri, New Hampshire, New York, Pennsylvania, and Wisconsin. The taxonomic status of this species in the United States is currently in question. It is now established that at least some of the reported records of *P. piceae* should be treated as *P. hemicryphus* Dalman. The spruce bud scale is found on spruce, particularly Norway spruce. Adult females are round, reddish brown, and closely resemble leaf buds of the host.

The spruce bud scale has one generation per year and overwinters as immatures. Adult females appear in spring, and eggs are retained in the adult female's body cavity. First instars appear in late spring and settle on the new growth of the host. Severe damage may involve the death of lower branches of the host. Chalcidoid wasps are often found associated with this scale.

The **tuliptree scale**, *Toumeyella liriodendri* (Gmelin), is apparently native to North America. In the Eastern United States, it occurs from New York to Florida and west to the Mississippi River. This soft scale prefers yellow-poplar and magnolias, although it is reported on several diverse hosts, including walnut and basswood. The tuliptree scale is found in native habitats and ornamental plantings. Adult females are large, convex, and are usually orange with black mottling near the body margin. Heavy infestations are common (fig. 33).

F-532855

Figure 33.—The tuliptree scale, *Toumeyella liriodendri*, on yellow-poplar.

The tuliptree scale has one generation per year except in southern parts of its range, where nonsynchronous populations suggest that there might be at least two generations. The species overwinters as second instars on the twigs of the host. In early spring the second instars resume feeding. Males appear in early summer and mating takes place. By late summer the greatly enlarged ovoviviparous adult females produce as many as 3,000 first instars. These immatures settle on the stems, feed, and molt to second instars late in the fall. Four kinds of tuliptree scale damage are reported on yellow-poplar *(176)*, ranging from greatly weakened trees with sparse foliage and many dead branches to trees with distorted trunks because of the death of a previous leader. Seedlings are frequently killed, greatly hindering future development of economically valuable stands of yellow-poplar. Natural enemies include five species of chalcidoid wasps, a flower fly, a pyralid moth, two lady beetles, and a fungus.

The **pine tortoise scale**, *T. parvicornis* (Cockerell), is native in North America. It is found in nearly every Eastern State and occurs as far west as the Dakotas. This soft scale seems to prefer Scotch, jack, and Virginia pines, but is also found on

Austrian, Swiss mountain, red, loblolly, shortleaf, white, and Chinese pines. The pine tortoise scale is common in natural habitats and ornamental plantings. Adult females are convex and are dark brown or black with reddish-brown or cream-colored mottling. It is possible that specimens identified as *T. parvicornis* may represent more than one species. Specimens collected from needles in the Southeast may be distinct, but host transfers would be required to establish this fact.

The pine tortoise scale has one generation per year in the Northern States *(763)*, two generations per year in Maryland *(789)*, and may have more in the Southern States. In the North, the species apparently overwinters as mated females on the stems of the host. By late spring, the adult females have greatly enlarged. In early summer, each female lays about 500 eggs, which hatch soon after being deposited. First instars develop into adults and mate in mid to late summer. Damage caused by the pine tortoise scale can be quite severe, particularly in the Northern States. Injury most frequently is incurred by seedlings and saplings, but heavy infestations may also damage mature trees. Infested trees may have chlorotic needles or many dead branches. In some cases, entire trees may be killed. Normally, this soft scale is held in check by its natural enemies, which include three chalcidoid wasps, nine lady beetles, and a pyralid moth.

Other *Toumeyella* species that may be found in eastern forests are *T. pini* (King), the **striped pine scale**, from Connecticut to Florida and west to Michigan on shortleaf, Swiss mountain, red, pitch, Scotch, Virginia, and lodgepole pines, and *T. virginiana* Williams & Kosztarab, the **Virginia pine scale**, from Florida, Georgia, Maryland, and Virginia on longleaf, loblolly, and Virginia pines. The striped pine scale is reddish brown with a central white stripe on the dorsum. The Virginia pine scale is uniform salmon pink to reddish brown and is frequently found beneath the bark.

Family Kermesidae
Gall-Like Scales

This family is unquestionably the least studied of the scale insects in the United States. Most taxonomic descriptions are based on color patterns of the gall-like adult females. These patterns have proved to be relatively unreliable. Two studies that clarify this problem have been completed *(34, 171)*. Kermesids are Holarctic in distribution and are almost entirely restricted to oaks (fig. 34). There are approximately 30 species in 2 genera in the United States. Of these species, perhaps only three occur in the East; biological information is available for only two.

F-519574

Figure 34.—Female scales of *Kermes* sp. on white oak twigs and leaves.

Kermes pubescens Bogue is known from Kansas and Maryland on white and bur oaks. Mature adult females are 2 to 3 mm in diameter and are brown with white bands. There is one generation per year, and in Maryland *(776)* the overwintering stage is the first instar. The overwintering first instar sheds its skin about the time that leaves first appear and then it moves to the new growth. Two more molts occur by late May or early June, and eggs are laid in late June to late July. The first instars move from the new growth and settle on main branches or the trunk, where they overwinter. In the spring, female crawlers move to new growth, including petiole and main leaf veins, but males remain on trunks and main branches. This species is reported to cause leaf distortion and flagging terminals of the oaks, especially in urban areas.

Kermes galliformis Riley, often mentioned as *K. kingii* Cockerell, is known in Massachusetts and Virginia on red and black oaks. There is one generation per year, and in Virginia *(522)* first instars overwinter in crevices in the bark. In early spring, the first instars molt and migrate. The second-instar females move to the new growth of the tree, usually at the base of a leaf petiole. The second-instar males move down the tree and often settle on the trunk; they also settle on wood chips, acorns, or stones early in June, and adults appear in mid-June. Mating occurs soon after the last molt, and egg laying begins in late July. A female may lay as many as 5,800 eggs, which hatch in early September. First-instar females tend to settle on stems of the host; first-instar males settle primarily on the trunk. Under circumstances of host stress, this scale is reported to cause flagging on heavily infested oaks. Natural enemies include a parasitic wasp, a predacious moth, and a lady beetle.

Recent studies on first instars[7] have revealed that only three of the nine eastern species can be differentiated morphologically. These are *K. pubescens*, *K. galliformis*, and *K. andrei* King. The latter is from white and red oaks in Massachusetts.

Family Eriococcidae
Eriococcids

Members of this family are principally temperate in distribution, although a small group of species occurs in the tropics. Eriococcids are frequently confused with mealybugs but are easily separated by the absence of the mealy, waxlike secretion typical of most mealybugs. There are three female instars and five male instars. The overwintering stage usually is the adult female or the egg. The family contains 54 species in 11 genera in the United States *(412)*. Species of *Cryptococcus* are placed in the family Cryptococcidae by some authors.

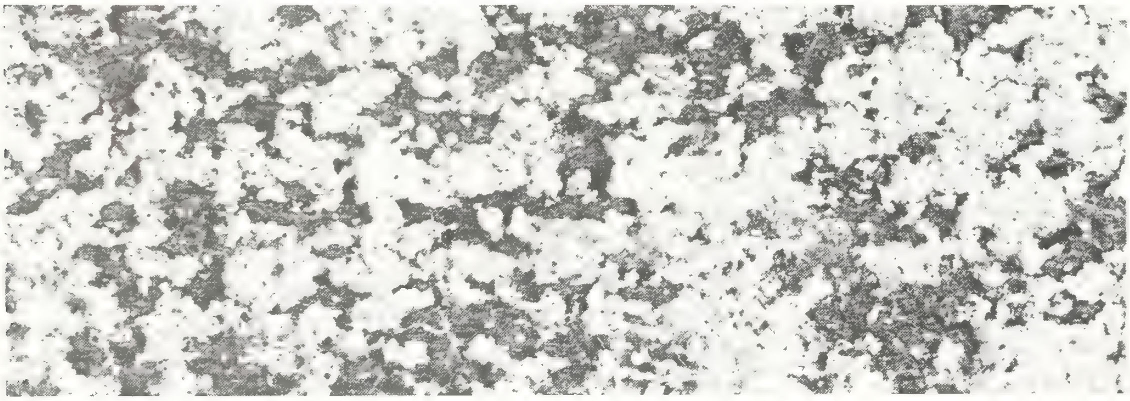
The **beech scale**, *Cryptococcus fagisuga* Lindinger, was apparently introduced from Europe around 1890 near Halifax, Nova Scotia, on European beech. The first United States record is from the Arnold Arboretum, Boston, Mass., in 1929, and there is evidence suggesting the presence of the scale there 10 years before. The beech scale is reported in Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont. It infests American, Oriental, and European beeches and is found in natural situations as well as ornamental plantings.

The life history of the species is variable, depending upon environmental conditions, but the general pattern is as follows: There is one generation per year, and males are unknown even in heavy infestations. The yellow eggs are laid in a

[7] Baer, R., and M. Kosztarab (personal communication). Virginia Polytechnic Institute and State University, Blacksburg, Va.

filamentous ovisac in late spring and summer and require a period of at least 20 days to hatch. First-instar crawlers appear in late summer or early fall and settle in cracks or lenticels on the trunk or large branches of the host. Soon after settling, the crawler produces a woolly secretion that encloses the body. The crawler is normally the overwintering stage, although eggs are occasionally found during this period. Through the winter the crawlers change in form from oval to pyriform. In the spring the crawlers molt to the second instar, which apparently is short in duration. This instar, like the adult female, is enclosed within a woolly, waxlike secretion, is legless, and is yellow. Adult females are present in the spring and most of the summer.

The first sign of an infestation is the appearance of isolated, minute, white woolly dots on the bark, usually near the base of the tree. As the infestation increases, the dots appear in the form of thin vertical lines and then as solid patches. On heavily infested trees, the trunks (fig. 35) and lower sides of branches may be completely whitened. Light infestations are not particularly injurious, but when they increase to about 15 scales per square centimeter, the bark is killed and turns brown. Depressions or pits in bark tissues around these wounds are frequently numerous on young trees. The death and shrinkage of groups of cells within feeding areas cause ruptures in the bark. Death of the tree does not usually occur until 2 to 5 years after infestation. A fungus, *Nectria coccinea* Pers. ex Fr. var. *faginata* Lohman, Watson and Ayres, gains entry through these ruptures. It penetrates the cambium and sapwood, killing tissues and interfering with the conduction and storage processes of the tree. Red fruiting bodies produced by the fungus become so abundant in some infestations that large areas on the trunk turn red. This infection leads to death of irregular-shaped areas of bark. Individual fungal lesions also coalesce and girdle the trunk, leading to crown deterioration and finally to death of the tree. The fungus is entirely dependent upon the scale for its incidence and spread.



F-502240

Figure 35.—Infestations of the beech scale, *Cryptococcus fagisuga*, on the trunk of beech.

Enormous quantities of beech have been killed; the only way to prevent such losses is through cutting and removal of infested trees *(1080)*. This is true despite the fact that some degree of natural control is provided by several predators, including *Chilocorus stigma* (Say). Winter temperatures of $-38°$ C are highly effective in the control of infestations exposed above the snow line *(45)*.

Another species of *Cryptococcus* may be found in eastern forests. *C. williamsi* Kosztarab & Hale is found on sugar or, rarely, red maple in Maine, New

Hampshire, New York, and Vermont. Probably it will eventually be found in most areas where there are natural stands of sugar maple.

The **European elm scale**, *Gossyparia spuria* (Modeer), apparently was introduced from Europe. In the United States it is reported from 33 States and probably occurs wherever elms are grown. It feeds on native and introduced species of elm and is found in natural habitats and ornamental plantings. Adult females are brown or greenish brown soon after they molt, but as the adults age, the body turns gray. A felted, waxy sack covers the bottom and lateral areas of the insect, leaving only the top center of the scale exposed. The first instar is yellow, and the second instar is reddish brown.

The European elm scale has one generation per year and has long-winged and short-winged adult males. The second-instar males and females overwinter in crevices on the bark of the host. In January, February, and March, the second-instar males molt to the prepupa, pupa, and adult. Mature males are most abundant in early spring. Molting of second-instar females to the adult stage is coincident with seed development of the elm host. After molting, the adult females move to the main branches, where mating takes place. When the elm seeds begin to fall, the adult females begin to form the characteristic waxy sacks. Egg laying begins 2 or 3 weeks after the first elm leaves are fully formed and continues into late summer. An individual female may lay as many as 400 eggs. The eggs normally hatch within an hour of deposition in the ovisac. Crawlers usually move to the undersides of leaves and feed near the primary veins. A small number of crawlers feed on the stems of the host. About 6 weeks after hatching, the crawlers molt to the second instar. Most of the second instars migrate from the leaves to the overwintering sites when the leaves begin to turn yellow. The European elm scale is frequently injurious, especially to young or recently transplanted elms. Symptoms include stunting of new growth, dieback of branches, premature leaf drop, and in small trees, death. Sooty mold grows on the large quantities of honeydew produced by this insect and gives the infested tree and surrounding objects an unsightly black, sticky appearance. Chemical control is frequently effective. Several species of chalcidoid wasps, lady beetles, and a green lacewing have been reported as natural enemies.

The **azalea bark scale**, *Eriococcus azaleae* Comstock, is apparently an Old World introduction. In the United States, it is reported from 34 States and probably occurs wherever azaleas are grown. Although normally found on azaleas, this species is also reported on willow, poplar, maple, hackberry, fremontia, huckleberry, pieris, rhododendron, gooseberry, and blueberry. It occurs on native and introduced hosts and is found in natural habitats and ornamental plantings. Adult females are bright red and are covered with many crystalline rods. A tough, pear-shaped ovisac is produced that encloses the adult female and the reddish-purple eggs. The first and second instars are purple or red.

The azalea bark scale has one generation per year in the North and two in the South. In northern areas the species overwinters as eggs or crawlers in the ovisac. The crawlers escape through a small hole at the posterior end of the ovisac and settle in branch or leaf axils. Second instars appear in early summer, and adults are prevalent in August. An individual female may lay as many as 250 eggs. In the South, the overwintering stage is the settled crawler or second instar. Adult females appear in early spring and lay their eggs in March or April. Adult females of the second generation mature in late summer and lay their eggs, which hatch in the fall. The scale causes dieback and gives heavily infested plants a leggy appearance. Chemical control is possible. A chalcidoid wasp, *Coccophagus immaculatus* Howard, often parasitizes this species.

Eriococcus quercus (Comstock), the **oak eriococcin**, is a native species restricted to oak. It is reported from Alabama, the District of Columbia, Florida, Georgia, Louisiana, Mississippi, New Jersey, Virginia, and several Western States. This scale is found in natural habitats and ornamental plantings. Adult females are reddish purple with a faint, yellow stripe down the center of the dorsum. The adult is covered with many crystalline rods that are noticeably longer along the body margin. The female produces a tough, pear-shaped ovisac which encloses the adult and the red eggs.

The oak eriococcin has two generations per year in northern California.[8] Males are common, and a single adult female may lay as many as 150 eggs. This scale normally feeds on the new growth stems of oak hosts. The oak eriococcin occasionally causes economic damage to ornamental plantings of oak. The chalcidoid wasp parasite, *Metaphycus eriococci* (Timberlake), has been found on this scale species in California.

Eriococcus gillettei Tinsley, the **Gillette eriococcin**, is native to the United States. It is reported from the District of Columbia, Florida, Maryland, Virginia, and several Western States, but it is undoubtedly present throughout the Southeast. This eriococcin is restricted to species of *Juniperus*, including California juniper, western juniper, and eastern redcedar. Adult females are yellow before forming an ovisac, but they eventually turn brownish purple. The body margin has a fringe of small crystalline rods. The adult female produces a tough, pear-shaped ovisac that encloses the adult female and the eggs. The first instars are brown when they first hatch and turn lemon-yellow after feeding. The second instars are yellow with a brownish mottling.

The Gillette eriococcin has one generation per year in Maryland, and males are common.[9] Eggs are the overwintering stage; they hatch in April or May. Second instars appear in June, and adults become prevalent in late June and early July. Egg laying begins in the fall and continues into early winter. The eggs are yellow when first laid, but by February they turn brown. An individual female lays about 50 eggs. Feeding takes place in protected areas on the foliage. This species occasionally builds up to economic proportions in ornamental plantings of juniper.

Family Lecanodiaspididae
Falsepit Scales

This family is a small, homogeneous group that is most abundant in the Southern Hemisphere. Members of the family form a thick waxy test (or cover) that encloses the body of the adult female and serves as an ovisac. The shape, color, and pattern of the test is frequently characteristic of a particular species. There are normally three instars in the female and five in the male. The family contains five species in one genus, *Lecanodiaspis*, in the United States *(615)*.

Lecanodiaspis prosopidis Maskell, the **common falsepit scale**, is native to North America and occurs from Pennsylvania to Florida and west to Missouri in the Eastern United States. It is found in ornamental and natural habitats on many trees and shrubs including: sweetgum, holly, catalpa, boxwood, euonymus, mountain-laurel, rhododendron, blueberry, buckeye, walnut, yellow-poplar, magnolia, mulberry, ash, camellia, basswood, azalea, hackberry, persimmon, dogwood, and elm. The test of the adult female is nearly circular, convex, yellowish white or brownish red, and has a dorsomedial longitudinal ridge. Eggs are reddish brown. The male test is smaller, more slender, and is bright yellow.

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[8] Miller, D. R. [n.d.]. Unpublished data on file at USDA ARS Syst. Entomol. Lab., Beltsville, Md.
[9] See footnote 8.

The common falsepit scale has one generation per year and overwinters as eggs in the test *(615)*. In Virginia, eggs hatch in mid-May, and adults appear in late July or early August. Egg laying begins in mid-September. Feeding takes place on the stems and twigs of the host. The common falsepit scale produces large pits and welts on its host, giving the plant a distorted, unnatural appearance.

Family Cerococcidae
Cerococcids

This family is a small, homogeneous group that is similar in external appearance to the falsepit scales. Adult female cerococcids form a thick, waxy test that encloses the body of the female and serves as an ovisac. The ovisac of cerococcids is generally rougher than the sac of falsepit scales and has a crawler exit hole that protrudes posteriorly. This family contains eight species in the genus *Cerococcus* in North America. Comprehensive studies of the genus have been published *(521, 616, 690, 711)*.

Cerococcus parrotti (Hunter), the **Parrott scale**, is apparently indigenous to North America and is reported in Arkansas, Georgia, Louisiana, Maryland, New Jersey, New York, Ohio, and Virginia in the East. Hosts include maple, bumelia, pecan, eastern hophornbean, persimmon, sweetgum, hackberry, hawthorn, sassafras, mahonia, basswood, elm, and buckeye. This species is found in natural and ornamental habitats. The test of adult females is oval, convex, grayish brown, brownish red, or yellowish brown, and has medial, mediolateral, and lateral longitudinal rows of conspicuous projections. The male test is smooth and narrow.

Parrott scale has one generation per year and overwinters as eggs in the tests in Virginia *(616)*. First instars appear in early to mid-May, and adults are present in late July. This species feeds on twigs, stems, and trunks of its host. It is apparently not an economic species. Four species of hymenopterous parasites have been reported as associated with this scale insect.

Cerococcus kalmiae (Cockerell) attacks mountain-laurel, azalea, camellia, mountain-ash, and persimmon in Georgia, Virginia, Maryland, Massachusetts, Ohio, and Pennsylvania.

Family Asterolecaniidae
Pit Scales

This family is a diverse aggregation of scale species that occur in all zoogeographic regions of the world. The most commonly encountered genus, *Asterolecanium*, contains several eastern forest pests. The adult females of this genus produce a thin, waxy test that covers the body. Many species produce a pit on the host as they feed. The family contains 19 species in 4 genera in the United States *(1045)*.

Three species of *Asterolecanium* occur on oaks in eastern forests. Because these species are similar in distribution patterns, field characteristics, and life histories, they are treated together. The species are the **golden oak scale**, *A. variolosum* (Ratzeburg), *A. minus* Lindinger, and *A. quercicola* (Bouché). These species may be found together on the same tree wherever oaks occur in the United States. The adult female is covered by a translucent greenish-yellow or brownish test that bears a similarly colored or whitish, waxy fringe around its margin. The test is usually slightly longer than it is wide and encloses the body of the female. Young adult females are yellow with a dark-brown streak around the body. As the adults age, they turn a uniform brown.

These three species of oak scales have one generation per year and overwinter as adult females. Oviposition occurs in late spring and early summer. During egg

laying, the adult female shrivels into the anterior end of the test and eggs fill its posterior portion. As the eggs hatch in late spring and early summer, crawlers emerge through a small opening at the posterior end of the test, settle, and within 24 hours form a noticeable pit *(138)*. One species may be ovoviviparous *(958)*. Second instars appear in mid-July, and adults are first observed in August. Males are unknown. These pit scales can be very destructive, especially to white oaks. In heavy infestations they cause distortion, poor growth, and dieback of the twigs. Leafing out in the spring may be delayed, and affected hosts may retain many of their leaves in the winter. Several chalcidoid wasps are associated with these scale insects.

Asterolecanium puteanum Russell, the **holly pit scale**, is native to the United States. It is known from 10 Eastern States from New Jersey to Florida and west to Pennsylvania and occurs on holly and bumelia. The holly pit scale may be found in ornamental plantings and natural habitats. Adult females are covered by a translucent, yellow-green test with a whitish-yellow or greenish waxy fringe around its perimeter.

The life history of the holly pit scale has yet to be worked out, but it probably is similar to that of the oak-infesting species. The holly pit scale is occasionally destructive to hollies *(293, 294)*. Heavily infested hosts may be stunted, have reduced amounts of foliage, and their branches may be distorted with pitted, roughened bark.

Other species of pit scales may be found occasionally in eastern forests. These include **oleander pit scale**, *A. pustulans* (Cockerell), observed in Florida, Louisiana, and Texas on many hosts; *A. arabidis* (Signoret), found in the District of Columbia, Massachusetts, New Jersey, New York, Ohio, and Pennsylvania on many hosts including privet, ash, phlox, and weigela; *A. bambusae* (Boisduval), in Alabama, Florida, Georgia, Louisiana, Mississippi, South Carolina, and Texas on various bamboo hosts; *A. miliaris miliaris* (Boisduval) and *A. miliaris robustum* Green, in Florida on bamboo.

Family Diaspididae
Armored Scales

The Diaspididae is the largest family of scale insects. Most armored scales form a shieldlike cover that is unattached to the body. The cover is normally composed of shed skins and wax produced by small glands on the body of the insect *(1169)*. The terminal segments of the adult female are fused into a strongly sclerotized pygidium. Scale coverings vary from thick, oystershell-shaped structures to translucent, circular structures. There are three instars in females and five in males. The family in the United States contains about 297 species in 83 genera *(904)*. The most comprehensive studies of the family are by Ferris *(405, 406, 407, 408)*.

The **hemlock scale**, *Abgrallaspis ithacae* (Ferris), is apparently native to North America and probably is present in all eastern areas where hemlock occurs. Distribution records have been compiled from Connecticut, Georgia, Indiana, Maryland, New York, Ohio, Pennsylvania, Tennessee, and Virginia. This armored scale is commonly found on hemlock, but is reported on fir and spruce; records from pine are probably erroneous. The species occurs in natural and ornamental habitats. The cover of the adult female is slightly convex, circular to oval, and is gray to black with white margins; the shed skins are subcentral. The body of the adult female is yellow-green, and the eggs are pale yellow. Petioles and undersides of needles are the areas inhabited.

The hemlock scale in Maryland has two generations per year and overwinters as second instars *(1172)*. Adults of the winter generation first appear in the middle of March, and eggs and first instars of the summer generation are present in June and early July. This generation develops rapidly, and by early to mid-July adults are present. Eggs and first instars of the winter generation are present from August to early October, and overwintering second instars are first observed in early September. Adult males are winged. Feeding by this scale produces yellow spots on the leaves; in heavy infestations, leaves will fall from the tree. An unidentified hymenopterous parasite has been reported *(1172)*.

Acutaspis morrisonorum Kosztarab, the **round conifer scale**, is native to North America and is known from Massachusetts to Florida and west to Michigan. It is found on many conifers including hemlock, spruce, fir, and juniper and infests natural and ornamental vegetation. The scale cover of the adult female is oval, flat, yellow-brown with a light margin; the shed skins are central. The body of the adult female is orange-yellow.

The round conifer scale is reported overwintering as second instars in Ohio *(689)*. It apparently does not damage its hosts significantly. Another species of *Acutaspis* that might be encountered in eastern forests is *A. perseae* (Comstock), the **redbay scale**. This species is most numerous in Southern States where it may become abundant enough to cause early leaf drop on several ornamentals. The adult female of the redbay scale has a reddish-brown cover that is flat and circular. Common hosts are persea and magnolia, but the species is polyphagous.

The **oleander scale**, *Aspidiotus nerii* Bouché, is probably introduced into North America. In the Eastern States, the species is found out of doors in southern areas and indoors elsewhere. The oleander scale is polyphagous, occurring on numerous shade trees and woody ornamental shrubs, and can be collected in natural and ornamental habitats. The cover of the adult female is flat or convex, is transparent white to opaque tan, and has a central, reddish-brown shed skin. The body is orange-yellow. Infestations normally occur on the leaves of the host but may be on the stems, bark, or fruit also. The status of this species is confused; the presence of biparental and uniparental "forms," and differences in biology, have led to the suggestion that there are two sibling species *(285, 473)*.

The oleander scale reproduces almost continuously, and distinct generations are therefore difficult to discern. Most workers state that the species has three or four generations per year. Eggs may hatch soon after they are laid, or nymphs may be deposited directly. Males may be present or absent. This species is sometimes a serious pest of such diverse hosts as olive, magnolia, and oleander. The oleander scale has a diverse array of natural enemies, including more than nine chalcidoid wasps, three lady beetles, and several fungi.

Aspidiotus cryptomeriae Kuwana, the **cryptomeria scale**, is from Japan; it is found in Connecticut, Indiana, Maryland, New York, and Pennsylvania in the United States. This armored scale occurs on an array of coniferous hosts including balsam fir, spruces, Douglas-fir, eastern hemlock, cryptomeria, white-cedar, cypress, yew, and pines and is found in natural and ornamental plantings. The cover of the adult female is circular or oval and is flat, grayish brown, with yellow, central shed skins. This species occurs on the leaves of its host.

The cryptomeria scale has two generations per year and, in Maryland, it overwinters as second instars *(1172)*. Adults of the overwintering population appear in March and April, and eggs are laid in June. Adults of the summer generation are

first present in mid-July, and eggs are laid in late August and September. Overwintering second instars appear in late September. Males are winged. This armored scale damages the leaves of cryptomeria and other conifers in Japan *(898)*. Natural enemies in Japan include two species of chalcidoid wasps and two lady beetles.

The **juniper scale**, *Carulaspis juniperi* (Bouché), is very closely related to *C. minima* (Targioni-Tozzetti), the **minute cypress scale**, and can be separated on the basis of microscopic characters only. The major difference is that the juniper scale has a macroduct between the median lobes and the minute cypress scale lacks this duct. These species are apparently introduced into North America and occur throughout most of the United States. They occur on a wide variety of coniferous hosts including cryptomeria, cypress, incense-cedar, juniper, sequoia, and northern white-cedar; juniper appears to be the most common host. Infestations are found in natural and ornamental habitats. The scale cover of the adult female is circular, convex, white, and has yellow, central shed skins. The body of the adult female and the eggs are yellow. The scale cover of the male is white with three faint longitudinal ridges and a yellow, terminal shed skin. The species occurs on the foliage of the host.

The juniper scale and the minute cypress scale apparently have only one generation per year in northern areas *(1162)*. Because first instars appear in warm southern and western areas several months in advance of cooler northern areas, and because only one generation occurs per year in northern Europe whereas two occur in southern Europe, it is probable that there are two generations per year in warm areas of the United States. However, only the minute cypress scale is known to have two generations *(33)*. Both species overwinter as gravid females and begin laying eggs in early spring in warm areas and late spring in northern regions. Crawlers are present in spring and early summer. Adult males are common. Heavily infested plants fail to produce new growth, have dead areas, and eventually die. Natural enemies include many chalcidoid wasps, several lady beetles, a nitidulid, and a coniopterygid.

The **elm scurfy scale**, *Chionaspis americana* Johnson, is probably native to North America and is known from almost every Eastern State. This armored scale prefers elm, but is also found on privet, *Prunus* spp., hackberry, sycamore, and basswood. Infestations occur in ornamental and natural vegetation. The scale cover of the adult female is oystershell-shaped, flat, white or dirty white, and has yellow or brown terminal shed skins. The body of the adult female without eggs is orange; with eggs it is red or purple; the eggs are red or reddish orange. The scale cover of the adult male is elongate, white, has three longitudinal ridges and a beige terminal shed skin. The adult male is red and may have long wings or short wing stubs.

The elm scurfy scale has two generations per year and overwinters on the bark as eggs *(1314)*. In Virginia, first instars appear in late April or early May and molt to second instars in late May or early June. Adults are present in June and July, and oviposition begins in July. First instars of the second generation are present in July, and adults appear in late August and early September. Overwintering eggs are laid in October and November. Females occur almost exclusively on the bark; males are predominantly on the undersides of leaves. Damage to elms may include the death of twigs, branches, or small trees. The feeding of second-instar males on leaves causes small chlorotic spots. Natural enemies associated with the elm scurfy scale include 11 chalcidoid wasps, a *Leucopis* fly, and a lady beetle.

The **dogwood scale**, *C. corni* Cooley, is native to North America and is reported from Massachusetts south to Louisiana and west to Kansas in the Eastern United

States. The scale cover of the adult female is white, elongate, expanded posteriorly, and has orange-yellow terminal shed skins. The scale cover of the adult male is white with three longitudinal ridges and a yellow, terminal shed skin.

The dogwood scale overwinters as eggs on the bark of the host *(605)*. Males have been reported. This species is occasionally destructive to ornamental dogwoods in the Midwest. Two chalcidoid wasps have been associated with this species.

The **scurfy scale**, *C. furfura* (Fitch), is probably native to North America and occurs throughout most of the United States. It is a common pest of many rosaceous plants, particularly apples; important forest hosts include hawthorn, mountain-ash, and *Prunus* spp. The scurfy scale is found in natural and ornamental vegetation. The scale cover of the adult female is white, oystershell-shaped with an expanded posterior, and has yellowish-brown terminal shed skins. The body of the adult female before egg formation is yellowish brown, but it turns red with the internal development of the eggs, which are also red. The cover of the male is elongate, white, with three longitudinal ridges. The body of the male is red. Males apparently have well-developed wings.

The scurfy scale has two generations per year; in Virginia it overwinters as eggs on the bark *(571)*. Overwintering eggs hatch in early spring, and first instars settle on the bark. Adults appear in early June, and eggs are laid in June and July. First instars of the second generation are found in mid-July, and adult development begins in mid-August. Overwintering eggs are laid in September and October. Males are apparently necessary for reproduction in at least some populations. Scurfy scale may be an important pest in apple and pear orchards but is not usually a pest in eastern forests. Natural enemies associated with this species include more than five chalcidoid wasps, a mite, and several lady beetles.

The **pine needle scale**, *C. pinifoliae* (Fitch), is closely related to *C. heterophyllae* Cooley, the **pine scale**, and can be separated on the basis of microscopic characters only. The pine needle scale occurs throughout the United States, whereas the pine scale is restricted to the East, primarily the Southeastern and Gulf States. Hosts include nearly all needle-bearing conifers including spruce, fir, pine, hemlock, and Douglas-fir (fig. 36). This scale occurs in natural and ornamental vegetation. The scale cover of the adult female is oystershell-shaped, white, and has transparent or light-yellow terminal shed skins. The body of the adult female and the eggs are purplish red. The cover of the adult male is elongate, white, and has three longitudinal ridges and a transparent terminal shed skin.

The pine needle scale has one or two generations per year. In the South to as far north as southern New York and Minnesota, it has two generations per year, whereas in northern areas, including Canada and in the Western States, there is only a single generation. Overwintering normally occurs as eggs, but it has been found that populations on Jeffrey pine from South Lake Tahoe, California, overwinter as gravid adult females, whereas those on lodgepole pine in the same area overwinter as eggs *(754)*. In Oregon it was found that adult females laid eggs throughout the winter into spring *(1161)*. In the Eastern States only biparental populations have been reported, but in California and Oregon biparental and uniparental populations are known. In central New York, the following life cycle is reported *(930)*. Overwintering eggs hatch in early May, second instars appear in late May, and adults are present in mid-June. Egg laying begins in early July, with first instars present from mid-July to early September. Adults appear in mid-August, and oviposition begins in early September. The pine needle scale can build to such large populations that the foliage of infested trees may have a gray appearance. Heavy

Courtesy Conn. Agric. Exp. Stn.
Figure 36.—Pine needle scale, *Chionaspis pinifoliae*, on needles of red pine.

infestations cause needles to turn yellow and may kill branches or whole trees. Infestations tend to be heaviest on lower branches. Ornamental plantings in urban areas are normally most severely damaged. Natural enemies include more than 10 chalcidoid wasps and 5 lady beetles.

Chionaspis nyssae Comstock, the **sour-gum scale**, is indigenous to North America and is known from 18 Eastern States from New York to Florida and west to Missouri. This species occurs almost entirely on black tupelo and water tupelo but is occasionally found on common sweetleaf, hackberry, hawthorn, and oak. The cover of the adult female is oystershell-shaped, slightly expanded posteriorly, white, and has yellow, terminal exuviae. The body of the adult female is yellow but turns pinkish red shortly before and during oviposition. Eggs are pink when laid but turn purple before hatching. The cover of the adult male is elongate, white, and has three longitudinal ridges and a yellow, terminal shed skin.

The sour-gum scale has two generations per year in Maryland and overwinters on the bark as mated adult females *(681)*. This scale may be found during the growing season on leaves and bark; females are most abundant on the bark and males on the leaves. Egg laying on the bark begins in early April; a single female may lay up to 80 eggs. First instars appear in mid-April on bark and early May on leaves; this stage is present throughout the growing season. Adults of the summer generation are first observed in mid-June. Winged males are most abundant, but wingless males are present in small numbers. Adults of the overwintering generation appear in late August. In the fall eggs are laid by leaf-inhabiting females but normally are

not produced by females on the bark. Adult males are predominantly wingless. Damage caused by this species is normally undetected; leaf areas around feeding sites are chlorotic. Natural enemies of this armored scale have not been reported.

Chionaspis salicisnigrae (Walsh), the **willow scurfy scale** or **black willow scale**, is probably native to North America. In the United States it is known from 32 States including most of those in the East. Hosts include poplar and willow. The species is found in natural and ornamental vegetation. The scale cover of the adult female is white, oystershell-shaped, is broadest centrally, and has translucent or yellow terminal shed skins. The body of the adult female and the eggs are purplish red. The scale cover of the adult male is elongate, white, has three small longitudinal ridges, and a yellow or brown terminal shed skin.

The willow scurfy scale has two generations per year in Colorado and overwinters as eggs on the bark of the host *(712)*. Eggs hatch in early spring, and adults are first present in mid-June. First instars of the second generation appear in early to mid-July, and adults are first seen in late August. Overwintering eggs are laid in September and October. The willow scurfy scale can seriously injure willows under certain circumstances. Natural enemies include two species of chalcidoid wasps and a lady beetle. Other species of *Chionaspis* that might be encountered in eastern forests are: *C. acericola* Hollinger on maple from Maryland, Missouri, North Carolina, Ohio, Pennsylvania, and Texas; *C. caryae* Cooley on hickory and walnut from 10 States including Connecticut to Florida and west to Missouri; *C. kosztarabi* Takagi on ash and American hornbeam from Georgia, Maryland, North Carolina, Ohio, Pennsylvania, Virginia, and New Jersey; *C. lintneri* Comstock on many hosts including viburnum, birch, walnut, alder, and serviceberry from 11 States from Maine to Florida and west to Indiana; *C. parki* Hollinger on sycamore from Indiana, Louisiana, Missouri, Ohio, Texas, and Virginia.

The **Florida red scale**, *Chrysomphalus aonidum* (L.), is apparently introduced into North America. In the United States it occurs out of doors in warm southern areas and is a common greenhouse pest in other areas. This species occurs primarily in ornamental plantings but is occasionally found in natural ones. The Florida red scale is truly polyphagous and is commonly found on holly, citrus, and palms. The scale cover of the adult female is circular, convex, dark reddish-brown, and has reddish central shed skins. The adult female and the eggs are yellow. The cover of the male is oval and smaller than the female's and has a subcentral shed skin.

The Florida red scale may have up to five or six generations per year *(364)*, depending on the climate. Eggs are laid and first instars settle on leaves, fruit, or rarely on the green stems of the host. Males appear to be necessary for reproduction. A single female may lay up to 334 eggs. The Florida red scale produces yellow areas on the leaves of the host. In heavy infestations entire leaves become chlorotic and drop from the tree. Natural enemies are numerous, including chalcidoid wasps, mites, fungi, lady beetles, thrips, and green lacewings. Natural control is normally effective in Florida.

Other species of *Chrysomphalus* that might be found in southeastern forests are *C. bifasciculatus* Ferris, the **bifasciculate scale**, and the **dictyospermum scale**, *C. dictyospermi* (Morgan). Both species are polyphagous.

Clavaspis ulmi (Johnson), the **elm armored scale**, is probably native to North America and occurs in nine Eastern States from New Jersey to Florida and west to Ohio. The preferred host is elm, but it is also found on maple, buckeye, catalpa, and basswood. The adult female cover is circular, convex, yellowish white to gray,

and has submarginal shed skins. The body of the adult female is yellow. The male cover is small and has submarginal shed skins.

The elm armored scale overwinters as second instars on the bark of the host, and first instars appear in early May in Ohio *(689)*. This species does not seriously damage its host. The only natural enemy known is a parasitic wasp.

The **Putnam scale**, *Diaspidiotus ancylus* (Putnam), is probably native to North America and occurs throughout most of the United States. The species is polyphagous but is commonly found on maple, basswood, and elm. The Putnam scale may be found in natural and ornamental vegetation. The adult female cover is circular, convex, gray or black, and has yellow or red subcentral shed skins. The body of newly matured adult females is yellow; on older females the anterior portion of the body is brown. The male cover is similar to that of the female but is oval and has subterminal shed skins.

The Putnam scale has two generations per year in Maryland[10] and Illinois *(1146)* and one in Iowa *(926)* and Ohio *(605)*. The species apparently overwinters as adult females on stems. In those areas where two generations occur, first instars appear early in the year and settle on leaves or stems; those that are on leaves are different morphologically from those on stems *(1146)*. Adult females and winged males are present in early July. Eggs and first instars appear in July, and adult females and wingless males are present in late summer and fall. Putnam scale is reported to kill twigs and branches on heavily infested trees. Natural enemies include more than three chalcidoid wasps, a lady beetle, a gall midge, and two fungus species.

Diaspidiotus liquidambaris (Kotinsky), the **sweetgum scale**, is native to North America and probably occurs in all areas where natural stands of sweetgum are found. This species is reported almost entirely on sweetgum and is found on natural and ornamental vegetation. This species forms a small gall-like structure on the leaves of its host. The cover of the adult female on the leaf has a large, yellow, central shed skin with white wax around the margin. On stems the adult female scale is white or gray with subcentral shed skins. The body of the adult female is yellow. The male cover is oval, white, and has a yellow submarginal shed skin.

The sweetgum scale has two generations per year in Maryland and overwinters as fertilized adult females on the bark *(1172)*. In Maryland, eggs and first instars appear in mid-May and are present until the end of June. Settling occurs almost entirely on the leaves. Adults are first present in mid-June. First instars of the second generation appear in early July and are present until early October. Settling occurs on both the leaves and the stems. Adults of the second generation appear in early to mid-September. Adult males are winged in the first generation and wingless in the second. The sweetgum scale does not cause serious damage to its host. A chalcidoid wasp has been reared from this scale.

Diaspidiotus osborni (Newell & Cockerell), the **Osborn scale**, is apparently indigenous to North America and is reported in nearly every eastern State. This scale is reported on several native tree genera but prefers oaks. The cover of the adult female is circular, flat, gray, and has yellow, subcentral shed skins. The body of the adult female and the eggs are yellow. The male cover is similar, but is smaller, oval, and has a submarginal shed skin.

Osborn scale has two generations per year and overwinters as mated adult females on stems in Maryland *(1172)*. Crawlers are present in Maryland in late May and June and again in August. Males of the first generation are winged; those of the

[10] Stoetzel, M. B. (personal communication). USDA ARS Syst. Entomol. Lab., Beltsville, Md.

second are apterous. This commonly encountered species is not a pest. Natural enemies include a chalcidoid wasp and a symbiotic fungus *(251)*.

Other species of *Diaspidiotus* that might be collected in eastern forests are *D. mccombi* McKenzie, the **McComb scale**, in 10 States from Pennsylvania to Florida and west to Louisiana on pine; and *D. caryae* Kosztarab, the **hickory scale**, in Ohio and Georgia on hickory.

Fiorinia externa Ferris, the **elongate hemlock scale** or **fiorinia hemlock scale**, has apparently been introduced from the Orient and is known in 11 Eastern States from Connecticut to Georgia and west to Ohio. Hosts include spruce, fir, Douglas-fir, yew, and hemlock, with the latter being the most common. It occurs in ornamental and natural vegetation. The external appearance of species of *Fiorinia* is unusual because the adult female is completely enclosed within the shed skin of the second instar. The second instar's shed skin is elongate, yellow to brown, and has the wax and shed skin of the first instar attached at the terminal end. The body of the adult female and the eggs are yellow. The cover of the male is elongate, white, has three longitudinal ridges, and a terminal shed skin. The body of the adult male is yellow.

The elongate hemlock scale is unusual in that it continues to reproduce and develop throughout the year in some locations; consequently, all stages are present at all times *(279)*. In Connecticut there is one complete generation and a second partial generation. Only about one-third of the population begins the second generation; the bulk of the population overwinters as adult females or eggs *(773)*. Adult females produce small batches of eggs which are replaced after hatching. Adult females may live up to a year. First instars settle on the undersides of needles and produce two kinds of waxy secretions. The first is a filamentous secretion produced by a pair of glands between the antennae. This secretion builds into a mass of tangled strands and becomes so abundant that it gives the undersides of infested needles a white appearance. The second secretion is produced posteriorly and eventually forms the wax covering over the body. Winged males are common. The elongate hemlock scale can cause serious damage to hemlocks in the Northeastern United States. Severe infestations cause yellowing of the needles, needle drop, and inhibited growth, giving the hemlock a thin, weak appearance. Natural enemies include two chalcidoid wasps and a lady beetle.

The **tea scale**, *F. theae* Green, was introduced from the Orient and occurs in 14 Southeastern States from Maryland to Florida and west to Louisiana. It is reported in several Northeastern States but probably is unable to winter out of doors. This species is truly polyphagous but seems to prefer holly and camellia. It occurs primarily in ornamental plantings. The second instar's shed skin is dark brown or black and has a dorsomedian ridge; the medial area is darkest. The first instar's shed skin is yellow and terminal. The body of the adult female and the eggs are yellow. The adult male's cover is elongate, white, has three longitudinal ridges, and a yellow, terminal shed skin.

The tea scale reproduces for an extended period, causing most infestations to have all stages present at one time. There are apparently many generations per year. Eggs are laid and crawlers settle on the leaves of the host. Males are common. Heavy infestations can severely damage the host. This species is generally considered the most serious scale pest of ornamental shrubs and trees in the Southeast and is perhaps the most difficult to control. A white powdery host plant is a good indicator of an infestation of tea scale. Natural enemies include at least one chalcidoid wasp, a fungus, and several species of lady beetles.

Other *Fiorinia* species that might occur in eastern forests are *F. fioriniae* (Targioni-Tozzetti), the **fiorinia scale**, from most Southeastern States on many hosts including palms and persea and *F. japonica* Kuwana, the **Japanese fiorinia scale**, from Virginia on hemlock and other conifers.

Hemiberlesia lataniae (Signoret), the **latania scale**, is so cosmopolitan that it is difficult to pinpoint an indigenous area. In the Eastern United States it is widespread, feeds on a wide variety of hosts, and occurs on ornamental and natural vegetation. The cover of the adult female is circular or slightly oval, convex, white to gray, and has a light-brown submarginal shed skin. The body of the adult female and the eggs are yellow. The cover of the male is gray, oval, and has a brown subterminal shed skin.

The latania scale has a variable number of generations per year, depending on the area; there are two generations per year in Maryland *(1172)*, three in Egypt *(379)*, and four in Israel *(32)*. In Maryland this species overwinters as second instars, and adults appear in middle to late April. Eggs are laid late in June, and adults are present in late July and early August. Eggs of the overwintering generation first appear in September, and overwintering second instars are found in late September. The latania scale has sexual and parthenogenetic populations. This species may build to very heavy populations and may cause dieback of twigs and branches of the host. Natural enemies include many species of chalcidoid wasps and lady beetles; green lacewings, fungi, and mites are also known to feed on the latania scale. Natural enemies usually keep populations of latania scales at low levels.

The **greedy scale**, *H. rapax* (Comstock), is of unknown origin. It is reported from 15 Eastern States from New York to Florida and west to Louisiana, although in northern areas it may be unable to survive out of doors. The species occurs in natural and ornamental vegetation and is polyphagous. The cover of the adult female is circular, convex, gray, and has a reddish-brown submarginal shed skin. The body of the adult female and the eggs are yellow. The male cover is oval, gray, and has a reddish-brown submarginal shed skin.

The greedy scale apparently has a variable number of generations per year, depending on the area, and feeds on all aerial parts of the host. Infestations usually have all stages present most of the year. Populations may be uniparental or biparental. Feeding may cause dieback, leaf drop, and unhealthy looking plants. Natural enemies include several chalcidoid wasps and lady beetles.

The **oystershell scale**, *Lepidosaphes ulmi* (L.), was probably introduced from Europe. It occurs in virtually every State in the United States and is polyphagous. Commonly infested hosts are lilac, beech, birch, ash, maple, poplar, willow, elm, boxwood, apple, pear, and *Prunus* spp. (fig. 37). This species may be found in natural and ornamental vegetation. The cover of the adult female varies according to host *(466)*. In Maryland, the cover of populations on poplar is reddish brown with two transverse yellow bands; on lilac and maple, the cover is dark brown. As the covers age, they turn grayish, dark brown, or black. The adult female scale is oystershell-shaped with brown or yellow terminal shed skins. The body of the adult female is white with a brown pygidium; eggs are white. The cover of the male is similar to the female cover but is smaller and has one shed skin. The body of the adult male is light yellow.

The life history of the oystershell scale varies according to host *(466)*. In Maryland, populations on lilac and maple have two generations per year, those on poplar and willow have one generation per year, and on boxwood there are one or two generations; all forms overwinter as eggs, but those from poplar hatch later in

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Figure 37.—Oystershell scale, *Lepidosaphes ulmi*, on bark of poplar.

the spring. Bivoltine forms in Maryland have crawlers in May and June and adults in June and July. Second-generation crawlers appear in mid-July, and adults are first present in September. Eggs are laid in October and November and subsequently overwinter. Univoltine forms have crawlers present in late May, with adult females first appearing in early July. In late July, females begin laying eggs, which subsequently overwinter. In Maryland, males were found in small numbers on boxwood, lilac, and maple (bivoltine) but were never found on poplar or maple (univoltine). The oystershell scale can be very destructive. Branches of trees are often obscured by scale covers. This scale frequently causes dieback and is often the apparent cause of the death of ornamental trees. It has been reported that entire forest stands of ash have been destroyed by this pest *(45)*. Many natural enemies are known, including parasitic wasps, lady beetles, and mites.

Other species of *Lepidosaphes* that might be collected in eastern forests are the **camellia scale**, *L. camelliae* Hoke, on camellia, holly, and magnolia in 14 States from New York to Florida and west to Louisiana; *L. pallida* (Maskell), **Maskell scale**, on many conifers, especially juniper, from 13 States from New York to Florida and west to Louisiana; and *L. yanagicola* Kuwana, primarily on euonymus from 11 States from Massachusetts to Georgia and west to Ohio.

Lopholeucaspis japonica (Cockerell), the **Japanese maple scale**, is probably native to the Old World. It occurs in 10 Eastern States along the Atlantic Coast from New York to Georgia and infests many hosts including maple, ash, and basswood. The species occurs in ornamental vegetation. Adult females occur within the shed skin of second instars in a similar manner to species of *Fiorinia*. The second instar's shed skin is dark brown with a thin layer of grayish wax and a yellow, terminal, first-instar shed skin is attached. The male cover is similar to that of the female but is smaller.

The Japanese maple scale has one generation per year in Rhode Island and in Tokyo, Japan, and two generations in Oita, Japan *(898)*. The overwintering stage is mated adult females in Tokyo and immatures in Oita. In Rhode Island first instars are reported in late June and early July. In Tokyo, winged males occur in mid-August. This species may kill branches on maples.[11] The Japanese maple scale is attacked by three parasitic wasps and two lady beetles.

[11] Davidson, J. A. (personal communication). Dep. Entomol., Univ. Maryland, College Park.

The **obscure scale**, *Melanaspis obscura* (Comstock), is native to North America and probably occurs in all Eastern States. The obscure scale is a serious pest of ornamental oaks, particularly pin oak and pecans. Other hosts reported in the literature are probably erroneous. The species occurs in natural and ornamental vegetation. The cover of the adult female is circular, slightly convex, grayish to black, and has shiny black subcentral shed skins. The body of the adult female is yellow after molting but changes to dark pink. The eggs are light pink. The male cover is similar to the female cover but is smaller, oval, with a subterminal shed skin. The body of the adult male is light brown.

The obscure scale has one generation per year in Maryland *(1170)* and Louisiana *(40)*. In Maryland, obscure scale populations on the white oak group of host species overwinter as crawlers, whereas on the red oak group of hosts, populations overwinter as second-instar males and females *(1171)*. In the spring adult females on red oaks first appear in late April, and egg deposition and hatching begin in late June. Overwintering second instars are first observed in mid-August. White oak populations molt to second instars in early May and are adults in mid-June. Egg laying and crawler emergence begin in early August. In Louisiana, the life history of populations on pecan is similar to that of red oak populations but is somewhat advanced chronologically. This scale infests the twigs, branches, and trunk of its host. Damage involves dieback of small-diameter branches, with the weakening of heavily infested trees. Pecan nut production may be reduced by this scale. Natural enemies include a large number of chalcidoid wasps, lady beetles, fungi, and mites.

The **gloomy scale**, *M. tenebricosa* (Comstock), is indigenous to North America and is found in 19 Eastern States from New York to Florida and west to Missouri. Hosts include a number of important forest trees; the most commonly infested hosts are species of maples, particularly soft maples. The species is found in natural and ornamental vegetation. The cover of the adult female is circular, convex, dark gray, and has black subcentral shed skins. The body of the newly molted adult female is light yellow but turns pink with age. The cover of the male is similar to that of the female except that it is smaller and is oval with a subterminal shed skin.

The gloomy scale in Maryland has one generation per year and overwinters as mated adult females *(1168)*. Eggs and first instars first appear in late June and early July, and adults first develop in mid-August. North Carolina populations were found to be somewhat advanced chronologically *(841)*. This scale is restricted to the twigs, stems, and trunks of its host. Natural enemies include several species of chalcidoid wasps and fungi.

Other species of *Melanaspis* that might be found in eastern forests are *M. nigropunctata* (Cockerell) on many hosts including ash and dogwood from the District of Columbia, Maryland, and Virginia; and *M. smilacis* (Comstock) on many hosts especially smilax from eight States from Maryland to Florida west to Louisiana.

The **black pineleaf scale**, *Nuculaspis californica* (Coleman), is apparently native to North America and is found throughout most of the United States. Hosts include Douglas-fir and most species of pine. This species is found in ornamental and natural vegetation. The cover of the adult female is oval, convex, black with light-gray margins, and has a yellow central area. Eggs are light yellow. The male scale cover is similar to the female's but is smaller and more elongate.

The black pineleaf scale has one generation per year in northern areas and two in southern areas. Warm weather during the fall or early winter may allow some overwintering scales to complete their development and begin a new cycle *(1176)*.

In the northeastern part of Washington State this scale apparently overwinters as second instars. Adults appear in late May and early June. Eggs and first instars are present in mid-July to early August. In Spokane, Wash., eggs hatch immediately after oviposition or hatch within the body of the adult female and are born as first instars *(371)*. In southern California, eggs are present in April and mid-May, first instars are present in May and June, and adults occur in June and July. Second-generation first instars are present in early August. Irregular abundance of infested trees in western forests has been hypothesized as a phenomenon of host-scale insect coevolution *(372)*. This species occurs on the needles of the host and prefers the basal portion of the needles on the flat surface. Severe infestations of black pineleaf scale cause the needles to turn yellow or red. Early needle drop and shorter needles give heavily infested trees a weak, unsightly appearance. Heavy infestations may kill branches or entire trees. Areas with large deposits of dust seem to be the most susceptible to attack by the black pineleaf scale. Natural enemies include at least four species of hymenopterous parasites and two species of lady beetles.

Nuculaspis tsugae (Marlatt), the **shortneedle evergreen scale**, is indigenous to Japan and occurs in Connecticut, Maryland, New Jersey, and Rhode Island. Hosts include fir, cedar, spruce, hemlock *(775)*, and yew *(904)*. The species in combination with elongate hemlock scale is a serious pest of hemlocks in both natural habitats and ornamental plantings, and may kill entire trees. The cover of the adult female is circular to oval, convex, dark gray, and has blackish, subcentral shed skins. The male cover is similar but is more elongate and has a subterminal shed skin.

The shortneedle evergreen scale has two generations each year in Connecticut. Overwintering is in the second instar and crawlers are present from late May to early July and early August to November *(773)*. This scale prefers the undersides of host needles and causes leaf chlorosis and premature needle drop. The main parasite of the shortneedle evergreen scale in Connecticut is a small wasp, *Aspidiotiphagus citrinus* (Craw).

A similar species, *N. pseudomeyeri* (Kuwana), occurs on cedar, northern white-cedar, cypress, juniper, and hemlock in New York and Pennsylvania.

Pinnaspis strachani (Cooley), the **lesser snow scale**, is apparently introduced and occurs out of doors in Alabama, Florida, Georgia, Louisiana, and Mississippi. It is a common greenhouse pest. The species is polyphagous, occurring on more than 200 hosts, and is normally found in ornamental plantings. The cover of the adult female is oystershell-shaped, flat, white, and has yellow terminal shed skins. The body of the adult female is reddish orange. The male cover is slender, white, has three longitudinal ridges, and a yellow terminal shed skin.

The lesser snow scale reproduces continuously and has many generations per year. Feeding occurs on all parts of the host, and males are common. Natural enemies are numerous, including parasitic wasps, lady beetles, and fungi.

Another species of *Pinnaspis* that might be found in eastern forests is the **fern scale**, *P. aspidistrae* (Signoret), observed on many hosts including palms and hollies, from nearly all Eastern States; in northern areas it is found in greenhouses.

Pseudaonidia paeoniae (Cockerell), the **peony scale**, has apparently been introduced from the Orient and is reported in 14 Eastern States from New York to Florida west to Louisiana. Common hosts are azalea, rhododendron, camellia, and holly. This species is most commonly encountered in ornamental plantings but is sometimes found in natural habitats in southern areas. The cover of the adult female is circular or oval, convex, brown, and is normally covered by the outer layer of the

host; the shed skins are subcentral and are yellowish orange. The body of the adult female and the eggs are purple. The male cover is smaller than the female cover and has a submarginal shed skin.

The peony scale has one generation per year in Japan and overwinters as mated adult females *(898)*. Overlapping generations are reported in the greenhouse *(1168)*. In southern areas there are probably many generations per year. Crawlers are present in Virginia in late May *(644)*. The peony scale occurs on the bark of its host. This species is a serious pest of azaleas, rhododendrons, and camellias in southern areas. It is reported to kill twigs and branches of its host. Natural enemies include a parasitic wasp, several lady beetles, and a fungus.

The **camphor scale**, *P. duplex* (Cockerell), is apparently native to the Orient and is found in Alabama, Florida, Georgia, Louisiana, and Mississippi in the United States. In Louisiana, nearly 200 hosts are reported, including persimmon, pecan, camellia, camphor-tree, oak, elm, and maple *(266)*. This species is primarily a pest of ornamentals but is found in natural habitats. The cover of the adult female is circular, convex, brown, and has yellow submarginal shed skins. The body of the adult female is white soon after molting but turns purple with age; eggs are light purple. The male cover is elongate, flat, brown, and has a yellow terminal shed skin.

The camphor scale has three generations per year in Louisiana and overwinters primarily as mated adult females *(266)*. First instars are present in Louisiana in late March, mid-June, and mid-August. The camphor scale may feed on the leaves or bark. Adult males are common and are necessary for reproduction in at least some populations. Damage usually does not involve killing trees, although it has been stated that camphor-trees may be killed within 6 months of attack *(1275)*. Normally, lower branches are killed leaving a weakened host. Natural enemies include at least nine parasitic wasps, two lady beetles, and *Platoeceticus gloveri* (Packard), the **orange basketworm**.

The **white peach scale**, *Pseudaulacaspis pentagona* (Targioni-Tozzetti) and *P. prunicola* (Maskell), the **white prunicola scale**, have been confused until recently *(280)*. Morphological and biological characters are useful in separating the species. The white peach scale has more perivulvar pores, more large macroducts, more small macroducts on the metathorax and first abdominal segment, and has fewer gland spines in the third space and these spines are usually bifurcate or trifurcate. The eggs of a single specimen of the white peach scale may be white or salmon or both *(93)*, whereas those of the white prunicola scale are all salmon. Both species have been introduced into North America from the Old World. The white peach scale is primarily a southern species and is common in the Southeast as far north as Maryland. The white prunicola scale is abundant in the Northeast but also is reported from Alabama, Florida, Louisiana, and Mississippi. The white peach scale occurs on a diverse range of hosts including 115 plant genera in Florida. In the United States it commonly is taken on peach, mulberry, and persimmon. The white prunicola scale has a more restricted host range including 21 genera of plants. In the United States it is commonly found on *Prunus* spp., particularly Japanese flowering cherry, and on privet and lilac. Both scales are similar in appearance; the cover of the adult female is circular, convex, white, and has yellow subcentral shed skins. The body of the adult female is yellow. The male cover is elongate, white, and has a yellow terminal shed skin.

The white peach scale has four generations per year in Florida *(644)* and three in Maryland *(280)*. The white prunicola scale has two generations each year in

Pennsylvania *(1164)* and three in Maryland *(280)*. First instars and eggs of white peach scale are present in early to mid-May, early to mid-July, and late August to early September. The life history of white prunicola scale is advanced compared with that of white peach scale. First instars and eggs are present in late April to early May, late June to early July, and mid to late August. Males are necessary for reproduction in at least some populations. These species are very serious pests of peaches and ornamental cherries. On some hosts they may build to such heavy infestations that entire branches are white. Natural enemies include parasitic wasps, lady beetles, a thrips, a mite, and a green lacewing.

Another species of *Pseudaulacaspis* that might be found in eastern forests is *P. cockerelli* (Cooley), which is polyphagous and occurs in Alabama, Florida, Georgia, Louisiana, and South Carolina.

The **Forbes scale**, *Quadraspidiotus forbesi* (Johnson), is apparently native to North America and occurs throughout the United States. It is polyphagous and is often found on hickory, dogwood, apple, and *Prunus* spp. This species occurs in ornamental and natural vegetation. The cover of the adult female is circular or oval, flat or convex, gray, and has orange, subcentral shed skins. The body of the newly molted adult female is reddish yellow but becomes darker with age. The male cover is smaller and more slender than the female cover. The adult male may be reddish brown or yellow, and has wings.

Forbes scale has two generations per year in North Carolina *(1214)* and Ohio *(643)*, and overwinters as mated adult females. In North Carolina adult females give birth to first instars. First instars are present from June to early July and again in August. Wingless males have been reported in mid-April in Ohio *(689)*. The species feeds on the stems and fruit of its host and can be a serious orchard pest in cherries, apples, and peaches in Michigan, Ohio, Illinois, Indiana, and North Carolina. Natural enemies include at least six hymenopterous parasites, several lady beetles, a mite, and two fungi.

Quadraspidiotus gigas (Thiem & Gerneck), the **willow scale**, is apparently introduced into North America and occurs in New York, Ohio, Pennsylvania, Rhode Island, and Wisconsin in the Eastern States. Hosts are willow and poplar. The willow scale may be found in ornamental or natural vegetation. The cover of the adult female is circular, convex, gray, and has orangish-yellow subcentral shed skins. The body of the adult female is yellow. The male cover is similar to that of the adult female but is smaller, more elongate, and has a subterminal shed skin.

The willow scale has one generation per year in Czechoslovakia *(721)* and Germany *(1066)* and overwinters as second instar males and females. First instars are sometimes present in the winter but are killed before spring. In spring the adults are present and egg laying occurs from June to September. Males are necessary for reproduction in at least some populations. First instars are present from June into winter. Feeding takes place on the bark of the host; this species encrusts the bark in severe infestations. Damage may include deformation of the bark, death of branches, or even whole trees. Natural enemies include approximately 15 species of parasitic wasps and 4 species of lady beetles.

The **walnut scale**, *Q. juglansregiae* (Comstock), is apparently native to North America and has a general distribution in the United States. This species is polyphagous and has been found on English walnut, holly, ash, elm, hickory, basswood, maple, sweetgum, yellow-poplar, among others. This scale occurs in natural and ornamental habitats. The cover of the adult female is circular, convex, grayish, and has reddish-brown subcentral shed skins. The body of the adult female

is orange to reddish orange. The male cover is similar to that of the female but is smaller, more slender, and has a submarginal shed skin.

The walnut scale has one generation per year and overwinters as second instar males and females in Maryland *(1168)*; overwintering second instars molt and mature from mid to late April. Eggs and first instars are present from late June to late September. Second instars begin to appear in early September. This scale may kill entire trees in some situations, although infested trees usually have dead lower branches and few leaves, giving them a weakened appearance *(605)*. Natural enemies include at least six species of parasitic wasps, two lady beetles, and a green lacewing.

The **European fruit scale**, *Q. ostreaeformis* (Curtis), is apparently native to Europe and is present in 11 Northeastern States from Maine to Pennsylvania west to Ohio. Hosts include a variety of plants, but rosaceous trees, especially apple, most commonly act as hosts. This species is found in natural and ornamental vegetation. The cover of the adult female is circular, convex, dark gray, and has orange or yellow subcentral shed skins. The male cover is similar to that of the female but is smaller, more slender, and has a yellow subterminal shed skin.

The European fruit scale has one generation per year in Germany *(1066)*, Czechoslovakia *(722)*, and New Zealand *(1024)*. In Europe the species overwinters as second instar males and females, but in New Zealand it overwinters as first or second instars. Adults are present in spring or early summer. Eggs and crawlers appear in late June or July. Males are essential in at least some populations. The European fruit scale may damage fruit trees in some parts of Europe and the United States. Natural enemies include at least five chalcidoid wasps, several lady beetles, and a fungus.

The **San Jose scale**, *Q. perniciosus* (Comstock), is Oriental in origin and occurs throughout the United States (fig. 38). It is polyphagous but is commonly collected on pyracantha, pears, *Prunus* spp., and many other rosaceous hosts. The species is found in natural and ornamental vegetation. The cover of the adult female is circular, slightly convex, gray, and has yellowish subcentral shed skins. The body of the adult female is yellow. The male cover is similar to the female cover but is smaller, elongate oval, and has yellow subterminal exuviae.

Courtesy Conn. Agric. Exp. Stn.

Figure 38.—San Jose scale, *Quadraspidiotus perniciosus*. Note large number of immature scales.

The San Jose scale may have as many as five generations per year, depending on the location. The overwintering stage in northern areas is predominantly settled first instars; in warmer areas all stages may be present, although first instars and gravid adult females seem to be most common. Parts of some generations are reported to aestivate during the first instar. It is not surprising that chemical control of this scale is difficult if one realizes that a single female may produce up to 400 eggs, and some of the resultant crawlers may develop rapidly while others go through a resting stage. After one or two generations there is little or no synchrony in first instar emergence, and nearly all stages are present at any one time *(468)*. First instars are laid directly on the host, and males are common. This species is most frequently found on stems, twigs, and fruit, but it also may be collected on leaves. The San José scale is perhaps the most destructive scale insect in the United States. If left unchecked it is capable of building up to very large populations and may kill entire trees. It is a very destructive pest of shade, ornamental, and fruit trees. Natural enemies include a large number of parasitic wasps, lady beetles, nitidulids, and fungi.

Other species of *Quadraspidiotus* that might be found in eastern forests are *Q. socialis* (Hoke) on oak from Georgia and Mississippi; *Q. taxodii* Ferris on baldcypress from the District of Columbia, Florida, Georgia, Louisiana, Maryland, and Pennsylvania; and *Q. tillandsiae* Takagi & Tippins on Spanish moss from Georgia.

Quernaspis insularis Howell, the **island oak scale**, and *Q. quercicola* Tippins & Beshear, the **false oak scale**, are native to North America. The latter is known only from Georgia, whereas the former is recorded from Arkansas, Florida, Georgia, and Texas. Until recently these species were considered to be the same as *Q. quercus* (Comstock), the **western oak scale** *(1185)*, which apparently occurs only in the Western States. Because of the confusion, the precise distribution of each species remains unclear. It is likely that the island oak scale and false oak scale will be found in the Eastern States only, from Ohio to Florida and as far west as Texas. These scales are reported only on species of oak and are found primarily in natural situations. The cover of the adult female is oystershell-shaped, gray or white, and has terminal shed skins. The male cover is elongate, white, with a terminal shed skin. The male cover of the island oak scale has a conspicuous longitudinal ridge, whereas the false oak scale lacks this ridge.

The life histories of the eastern species of *Quernaspis* are unknown, but the western oak scale overwinters in California as adult females or second instars *(1028)*. In all three species the adult female occurs on the stems and twigs of the host, whereas the second instar male covers are found on the leaves. A single parasitic wasp is known on the western oak scale; natural enemies of the other two species have not been reported.

The **euonymus scale**, *Unaspis euonymi* (Comstock), is probably native to the Old World and will undoubtedly be found wherever euonymus is grown. Although it is normally found on euonymus, it is also reported on 30 other genera of hosts including bittersweet, holly, and pachysandra *(485)*. This species normally is found in ornamental plantings but occasionally is present in natural situations. The cover of the adult female is oystershell-shaped, convex, dark brown, and has yellow or brown terminal shed skins. The body of the adult female and the eggs are normally yellow or yellow-red. The male cover is elongate, white, has three longitudinal ridges, and a yellow terminal shed skin. The male is pale orange and winged.

The euonymus scale may have two or three generations per year, depending on the locality. The primary overwintering stage is the mated adult female, although

immatures may also overwinter *(194)*. In Maryland, first instars are present from late April or early May to late June and early or mid-July to October *(485)*. In Massachusetts first instars are present in early June and August. In Ohio they are present from May through June and again in late July through August *(689)*. This species may be found on the stems, leaves, or fruit of its host. The euonymus scale can build to such heavy populations that it may cover much of the surface area of a particular host. Under such circumstances the plant will become white with male covers (fig. 39). Upper surfaces of leaves become spotted with yellow areas where scales are feeding on the undersurface. Heavily infested plants may lose many of their leaves and become leggy in appearance. Natural enemies include at least seven species of parasitic wasps, one species of lady beetle, a green lacewing, and two mites. None of these natural enemies has been reported as an effective biological control agent.

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Figure 39.—The euonymus scale, *Unaspis euonymi*, on euonymus.

Velataspis dentata (Hoke), the **dentate scale**, is apparently native to North America and is found in Alabama, Florida, Georgia, Louisiana, and Mississippi in the Eastern United States. It is found on a variety of hosts including bumelia, hackberry, magnolia, willow, poplar, catalpa, maple, and others. The cover of the adult female is unusually elongate, flat, white to light green, and has terminal shed skins. The male cover is similar but is shorter and broader. The life history of this species has not been studied. It is normally found on the leaves of its host.

Order Lepidoptera—*Butterflies, Moths, Skippers*

This is the second largest order of insects and one of the most important economically. More than 5,000 species occur in the Eastern United States alone, and many are serious pests of forest, shade, and ornamental trees. The adults differ considerably in appearance from those in all other orders and are not difficult to recognize. The wings and practically all other parts of the body are typically covered by a layer of short, flattened hairs, or scales, which rub off like dust when the insects are handled. The mouth parts, when present, are in the form of a long, slender, flexible tube that is carried coiled up like a watch spring beneath the head. The wings are usually very broad and subtriangular in form; the front pair is larger.

Moth, butterfly, and skipper adults usually differ in habits and appearance as follows: (1) Moths usually fly at night and are frequently attracted to lights; butterflies and skippers fly in the daytime. (2) Moths usually have the wings wrapped around the body, folded rooflike on the abdomen, or spread horizontally while at rest; butterflies usually fold their wings above the back in a vertical position; skippers usually hold the front and hindwings at a different angle. (3) Moth antennae are usually threadlike or featherlike; butterfly antennae are threadlike and clubbed at the tip; the antennae of the skippers are usually recurved or hooked.

Lepidopterous larvae are all very similar in structure and are known as caterpillars. They are usually cylindrical in shape and, besides the head, the body is composed of 13 segments, 3 thoracic and 10 abdominal. Each thoracic segment bears a pair of jointed legs, terminating in a single claw, whereas the abdominal segments bear unjointed fleshy projections of the body called prolegs, typically one pair each on segments 3 to 6 and 10. Occasionally, some or all of the prolegs are missing. A distinctive feature of the prolegs of caterpillars is the presence of fine hooks, known as crochets; these are usually in a circle at the apex, but also may form bands or rows. Another important characteristic of the Lepidoptera is the ability of the larvae to produce silk. Many larvae use this material in making cocoons, and some use it for making shelters. The first instars of certain species also frequently drop down from the crowns of trees in large numbers when disturbed, hanging suspended at the ends of long strands of silk. Many of these are often borne aloft by the wind and transported for considerable distances. Many nearly full-grown larvae descend the tree in search of better food or pupation sites.

True silk moth larvae typically spin silken cocoons in which to pupate. Some miscellaneous groups form tough silk or parchmentlike cocoons, which often include debris. The pupae of many others are naked or are enclosed in slight cocoons attached to leaves or other surfaces. Depending on the species, cocoons may be found in the soil, in tunnels in wood, or in other larval habitats. The caterpillars of butterflies usually do not make cocoons. Their pupae are naked and are commonly known as chrysalids. They are often attached to leaves or twigs from

which they hang head down. Some, such as those of the families Papilionidae and Pieridae, are girdled with a strand of silk and do not hang head down. Skippers pupate in cocoons made of leaves fastened together with silk.

The order Lepidoptera contains numerous destructive forest and shade tree insects. Several species such as the spruce budworm, the forest tent caterpillar, and the gypsy moth often occur in outbreaks covering tens of thousands of hectares of woodlands, and losses are very great. Large volumes of timber may be killed, and larger volumes are lost through reduced growth of surviving trees. Many other species cause serious losses by boring into and destroying the buds and shoots of seedlings and young trees in forest nurseries and plantations, or by mining the tissues between the upper and lower surfaces of leaves. The attractiveness of shade trees, parks, and other recreational areas is often reduced or destroyed by these insects, fire danger is increased, and wildlife habitats are impaired.

The literature on these insects is vast, and the references given here for further treatment are few, but selected because of their broad coverage *(140, 161, 318, 352, 374, 413, 433, 440, 447, 575, 586, 587, 614, 672, 785, 865, 1002, 1003, 1004, 1007, 1204)*.

Family Eriocraniidae
Eriocraniids

Larvae of the very small species *Dyseriocrania auricyanea* (Walsingham) mine the leaves of oak, chestnut, and chinkapin in the Eastern States. The mines are often blotchlike and may encompass up to one-fourth of the leaf area. Damage is sometimes a matter of concern to owners of Asiatic chestnut orchards.

Family Hepialidae
Hepialid Moths

Hepialid moths sometimes attract attention late in the day when they are seen flying swiftly in a zigzag manner, close to the ground. They are medium to large in size, with rather long, stout abdomens and a wingspread of 25 to 100 mm. The better known species are yellowish to brown or ashy gray with silvery-white spots on the wings. The larvae are long-headed and nearly naked, have five pairs of prolegs, and normally live as root borers. *Sthenopis argenteomaculatus* (Harris) breeds in the base of the trunk and roots of alder in the Northeastern States; *S. thule* (Strecker) breeds in the roots of willow.

Family Nepticulidae
Nepticulids

This family includes the smallest of the Lepidoptera, the adults of some species having wingspreads of only 3 mm. Because of their minute size, their retiring habits, and their irregular flight, they are seldom seen. The larvae of most species are leafminers; a few construct mines in the bark of their hosts. Many of the more common deciduous trees in the Eastern United States serve as hosts for one or more species. The larvae are slightly flattened, and their heads are rather deeply retracted into the prothorax. When full grown, the majority vacate their mines, drop to the ground, and spin dense, flattened cocoons in the duff *(147)*.

The genus *Nepticula* contains many leafmining species. Eggs are deposited on either surface of a leaf, usually along the side of a vein. The larvae of certain species mine only one side of a leaf; some mine both sides; and some mine different sides at different periods of larval life. The mines may be linear and gradually widen as they are extended, or, at some point, they may enlarge suddenly into a blotch. Winter is spent in the larval stage. There are one to four generations per year, depending on the species.

The genus *Ectodemia* contains a number of species, the larvae of which either form galls on leaf petioles or twigs or mine the bark of various trees. Members of the genus have only one generation per year. *E. populella* Busck, the **poplar petiole gall moth**, forms pea-size globular galls on the petioles of poplar leaves. *E. heinrichi* Busck larvae excavate flattened, oval, spiral mines in the bark of young branches of pin oak.

The **hard maple budminer**, *Obrussa ochrefasciella* (Chambers), bores into and destroys the buds of hard maple. The larvae spend the winter in axillary buds and migrate to the main buds in the spring *(701)*. Heavy outbreaks of *O. sericopeza* (Zeller), an introduced species that mines the seed pods and leaf petioles of Norway maple, have been recorded in Maine. Damaged leaves and seed pods drop prematurely. There are two and perhaps three generations per year.

Family Incurvariidae
Incurvariids

The **maple leafcutter**, *Paraclemensia acerifoliella* (Fitch), is the only member of this family of economic importance in eastern forests. It occurs in southeastern Canada and in the Northeastern States south to Virginia and west to Illinois. Its favored host is sugar maple, but the larvae also feed on the leaves of red maple, beech, birch, elm, and hophornbeam. The adult has long, narrow, pointed wings and a wingspread of 8.5 to 13 mm. The forewings are steel blue and fringed with black; the hindwings are pale smoky brown, translucent, and bordered with a pale-brown fringe of long scales. There is a dense tuft of bright orange-yellow scales on the top of the head, the thorax is steel blue, the legs whitish, and the abdomen dark brown. First-stage larvae are flattened, about 1.5 mm long, and they taper from the front to the rear. Full-grown larvae are slender, flattened, and usually dull white with amber-brown heads and a broad longitudinal stripe. They are about 6 mm long. Pupae are light yellowish brown, about 5 to 6 mm long. Abdominal segments two to eight bear transverse rows of short, stiff, backward-pointed spines on the back.

In Canada, adults appear in the spring about the time the leaves open, and deposit their eggs singly in pockets on the undersides of the leaves. When the larvae hatch, they bore into the leaf tissues and feed as miners for about 10 days to 2 weeks. Then, each larva cuts a round disk out of the leaf and makes an oval, movable case in which it resides as a casebearer. As it grows, it cuts out larger oval pieces and attaches them to its case. In order to feed, it attaches the case to a leaf and reaches out from it in a circle as far as it can. The uneaten center of this circle often drops out, leaving a hole up to 12 mm in diameter in the leaf. When the larvae become full grown, they drop to the ground to pupate. Winter is spent in the pupal stage, and there is one generation per year *(1039)*.

The maple leafcutter is often a pest in sugar maple stands, especially in sugar maple orchards. The trees may be severely defoliated, often for several years in succession.

Family Heliozelidae
Shield Bearers

Shield bearer moths are rather small and have lanceolate wings. The larvae are strongly flattened and spend most of their lives mining the leaves of their hosts.

The **tupelo leafminer**, *Antispila nysaefoliella* Clemens, feeds on tupelo throughout the eastern part of the United States. The adult is dark brown and has a wingspread of 7 to 8 mm. The pale-green larvae feed within leaf tissues, forming blotchlike mines. A full-grown larva spins a cocoon within the mine and then cuts

through the upper and lower layers of the leaf around the cocoon, forming a case. The case, which encloses the larva and cocoon, drops to the ground. Once there, the larva fastens the case to some object by means of silken threads and then pupates. Heavily infested trees may turn completely brown by midsummer.

The **resplendent shield bearer**, *Coptodisca splendoriferella* (Clemens), also occurs in the Eastern United States. Larvae mine the leaves of apple, cherry, and related hosts. They pupate in cases attached to the limbs and trunks of their hosts.

Family Psychidae
Bagworm Moths

Members of this family have the interesting habit of spending the entire larval stage within silken bags. The bag is usually strong, tough, and camouflaged by an outer layer containing bits of twigs and leaves. Newly hatched larvae begin to spin bags about their bodies as soon as they start to feed and they continue to enlarge the bags as they grow. An opening is maintained at the top of the bag, through which the head and several segments of the body protrude when the larva is moving, feeding, or enlarging its case. There is also a smaller opening in the bottom of the bag, through which excrement drops out. About 24 species have been recorded from the Eastern United States *(282)*. The species occurring in Texas are discussed *(646)*.

Oiketicus abbotii Grote occurs over much of the Atlantic and Gulf Coastal Plains from North Carolina to Texas. It feeds on many species of trees such as baldcypress, live oak, bayberry, sycamore, elm, hackberry, sweetgum, and willow. It is noted for the rather large bag, about 70 mm long, which the larva constructs. Small twigs used in its construction are placed in a circular pattern around it. *Psyche casta* (Pallas) feeds on lichens, mosses, and the beech scale in Massachusetts. The larvae occasionally climb up on the sides of houses in such large numbers that they are a nuisance. *Basicladus celibatus* (Jones) frequently attaches its bags to the lower trunks of oaks and pines in coastal areas from North Carolina to Florida. The larvae are general feeders on low vegetation and may feed on trees.

The **bagworm**, *Thyridopteryx ephemeraeformis* (Haworth), is widely distributed in the Eastern United States and attacks a wide variety of trees. Northern white-cedar and redcedar appear to be preferred, but many other conifers and hardwoods such as pine, spruce, black locust, sycamore, willow, maple, elm, basswood, poplar, oak, baldcypress, and persimmon are also attacked. The male moth is sooty black, densely hairy, and has a wingspread of about 25 mm. Females are wingless, have no functional legs, eyes, or antennae, and are almost maggotlike in appearance. The body is soft, yellowish white, and practically naked except for a circle of woolly hairs at the posterior end of the abdomen *(610)*. Full-grown larvae are dark brown and about 18 to 25 mm long. The head and thoracic plates are yellowish and spotted with black.

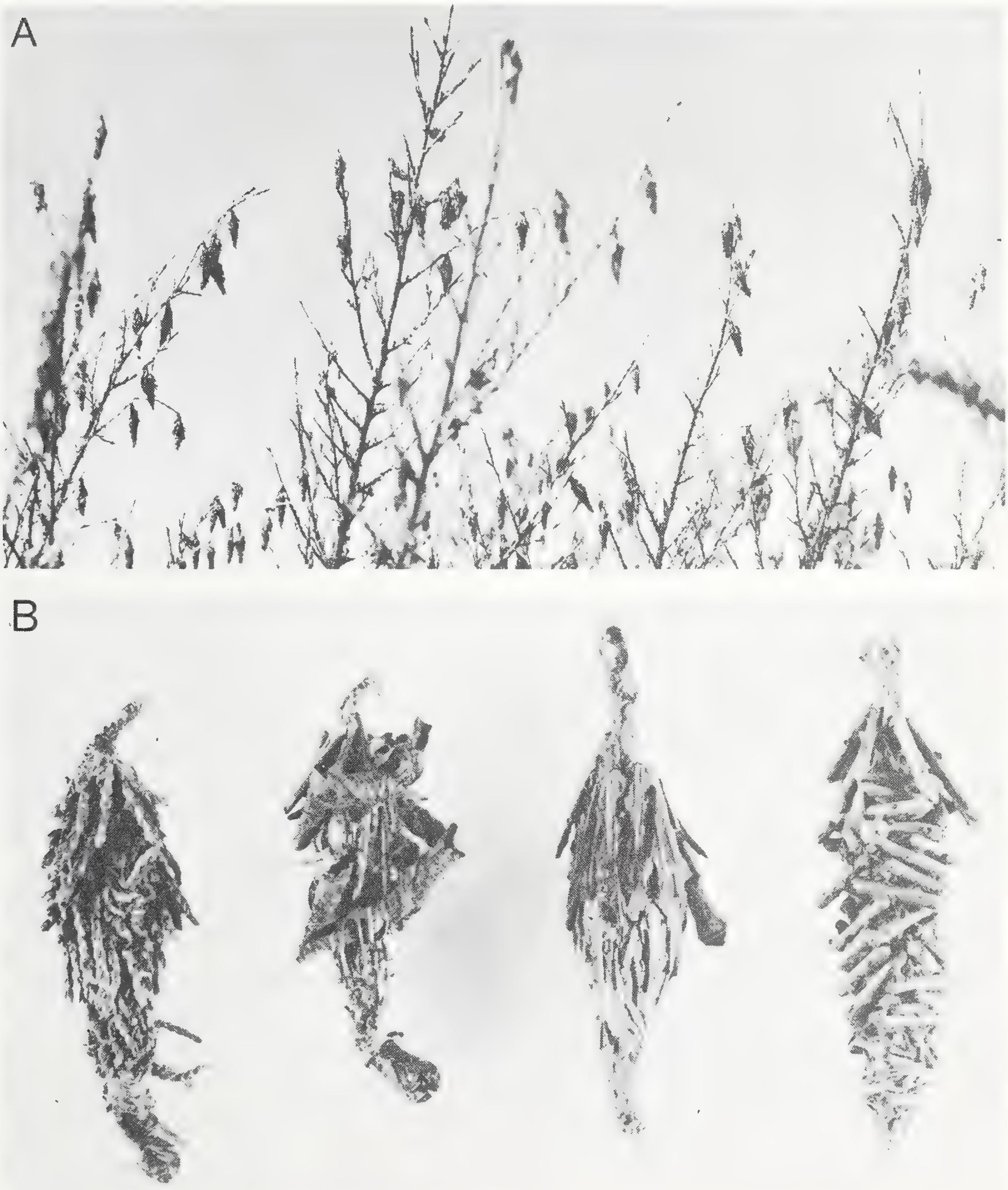
Male bagworm moths emerge in the fall, fly to the females, and mate. The female remains in her larval bag and deposits her eggs in the pupal case in the mass of scales she shed. Winter is spent in the bag in the egg stage and the eggs hatch during the following May or June. The larvae feed on the surface of leaves at first; later entire leaves are consumed. Mature larvae attach their bags to twigs (fig. 40) with silk and pupate in them. There is one generation per year.

The bagworm is most important as a pest on shade trees and ornamental shrubs growing in yards and hedges, along the streets of cities and towns, and in parks and other recreational areas. Large numbers of northern white-cedar and other conifers are lost each year as a result of complete defoliation. Many others only partly

defoliated are weakened and rendered unsightly. Damage to forest trees is usually not very severe *(699)*; however, heavy infestations do occur occasionally in stands of Atlantic white-cedar and black locust, especially in the Deep South.

Low winter temperatures, bird predation, and parasitism by the ichneumonid, *Itoplectis conquisitor* (Say), are often particularly effective in bagworm control. Handpicking and burning of overwintering bags is also helpful in control, especially on small trees and ornamentals *(1349)*.

Cryptothelea gloverii (Packard) occurs from South Carolina to Florida and westward along the Gulf Coast. Its hosts are recorded as two species of scale insects, and persimmon, oak, hickory, acacia, hawthorn, and sour orange. The male moth is dark or dark red and has a wingspread of 14 to 18 mm. Females are 9 to 10 mm long. Their cases may be covered with fragments of scale insects, bark, fruit rinds, or leaves.



A, F-508522
B, Courtesy H. G. Schabel, Univ. Wis.

Figure 40.—Larval cases of the bagworm, *Thyridopteryx ephemeraeformis*: A, cases on an infested tree; B, closeup of cases.

Family Lyonetiidae
Lyonetiids

This family contains numerous species of tiny moths, the majority of which belong to the genus *Bucculatrix*. At least 18 species are known to feed on trees in eastern America *(148)*.

Adults of the genus *Bucculatrix* have the vertex of the head rough or tufted, and the face smooth which extends into a point below the eyes. The wings are lanceolate and broadly fringed with markings of brown, black, or silver. Larvae are cylindrical and greenish and have well-developed legs and prolegs. Pupation occurs within longitudinally ridged or ribbed silken cocoons.

Bucculatrix pomifoliella Clemens, the **apple bucculatrix**, is widely distributed in southern Canada and the Eastern United States. Its hosts are apple, black cherry, serviceberry, and hawthorn. Full-grown larvae are dark yellowish-green tinged with red, have brown heads, and are about 6 mm long. Winter is spent in cocoons spun on the lower surfaces of twigs, foliage, or fruit. The color of the cocoons differs according to the larval host—white on apple, pale tannish-ochreous on serviceberry, reddish-brown on black cherry, and dark brown on hawthorn. There is one generation per year in the North and two in the South.

The **birch skeletonizer**, *B. canadensisella* Chambers, is a common species in southern Canada and throughout the birch-growing regions of the Eastern States from Maine to North Carolina and Minnesota. Paper birch appears to be the favored host, but several other birches and possibly alder are also attacked. The adult has a brown and white body and a wingspread of about 9 mm. The forewings are marked with diagonal white bars and the hindwings have broad fringes of scales. Full-grown larvae are yellowish green, with hairs projecting from white tubercles, and are about 6 mm long.

Adults are active from late June to late July and lay their eggs singly here and there over the leaves. Hatching occurs in about 2 weeks and the young larvae enter the leaves to feed, forming serpentine mines. From 3 to 4 weeks later they emerge through the lower surface and spin webs within which they molt. After molting, they leave the webs and feed externally as skeletonizers until they reach maturity. Full-grown larvae drop to the ground and spin short, brown cocoons in which they spend the winter on the undersides of fallen leaves or other debris. There is one generation per year.

Outbreaks occur at frequent intervals, often over large areas, and last for 2 or 3 years. Defoliation may be severe but it seldom causes much tree mortality. The defoliated trees may be so seriously weakened, however, that they are attacked and killed by the bronze birch borer.

The **oak skeletonizer**, *B. ainsliella* Murtfeldt, occurs from southern Canada and the Lake States to North Carolina and Mississippi. Its hosts are various species of oak and chestnut. The adult has a wingspread of about 8 mm. The forewing is largely blackish, with paler areas outlining an oval, blacker patch on the inner margin. Full-grown larvae are yellowish green and about 5 mm long.

The winter is spent in the pupal stage in cocoons. The cocoons are white, about 3 mm long, and ridged longitudinally. Adults are active in April and May and again in July and August. Eggs are laid on the undersides of leaves. First-stage larvae enter the leaves to feed, forming serpentine or blotch mines. Older larvae feed externally on the lower surface, often completely skeletonizing the leaves (fig. 41) *(475)*. Two generations per year have been recorded in Michigan and Massachusetts. Outbreaks occasionally occur over large areas.

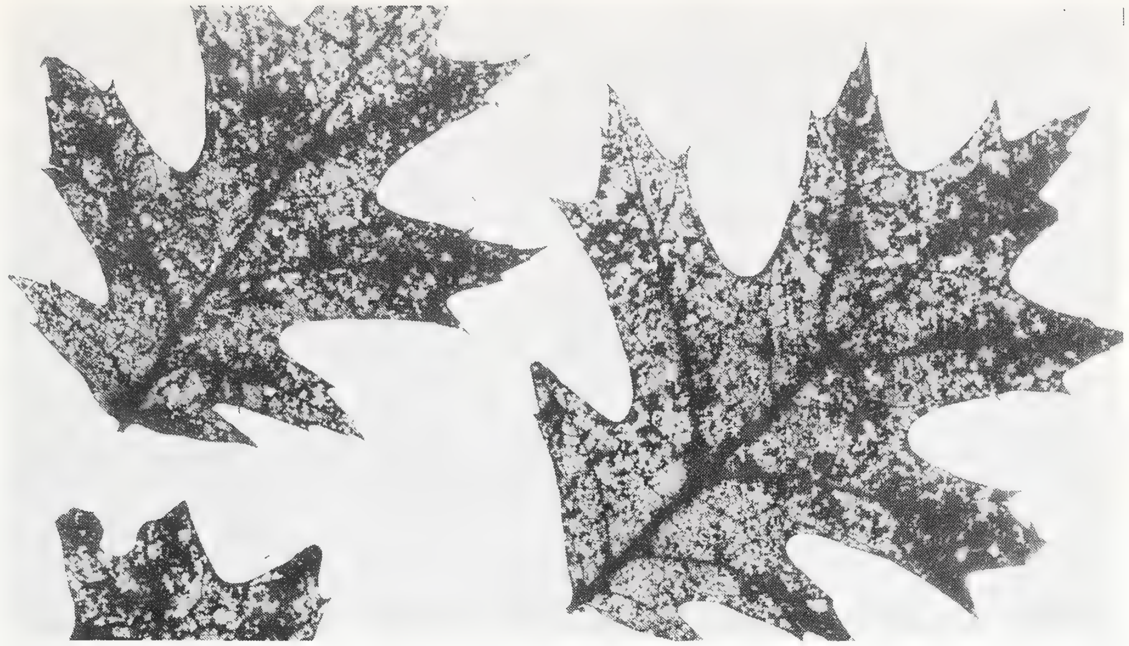


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Figure 41.—Red oak leaves skeletonized by feeding of larvae of the oak skeletonizer, *Bucculatrix ainsliella*.

Other widely distributed species of *Bucculatrix* and their hosts are as follows: *B. packardella* Chambers—various oaks and occasionally beech; *B. quinquenotella* Chambers—oaks; *B. luteella* Chambers—white oak; *B. recognita* Braun—various white oaks, especially bur; and *B. coronatella* Clemens—sweet birch.

Family Gracillariidae
Leafblotch Miners

The family Gracillariidae, the largest of the leafmining families of Lepidoptera, is represented in North America by more than 200 species *(380, 910)*. This family is currently undergoing revision. The adults are tiny and beautifully arrayed in shining scales and plumes, and their more or less lanceolate wings are overlaid with glistening scales of silver or burnished gold. While an adult is at rest, the front part of the body is raised and the wingtips touch the surface on which it sits. Early instars are very flat and usually feed first within mines in the leaves. Later, some feed mostly on the leaf tissues from within tentiform mines or they skeletonize the leaf from shelters made by folding over parts of leaves.

The full-grown larvae of most species spin silken cocoons, usually within feeding mines or shelters, in which to pupate. Winter is spent as larvae, pupae, or adults, depending on the species.

The **solitary oak leafminer**, *Cameraria hamadryadella* (Clemens), occurs throughout much of the Eastern United States and southeastern Canada. Its hosts are various species of oak, especially those in the white oak group. The adult has a wingspread of about 6 mm. The forewings are pale with bronze patches, and the hindwings are silvery with broad fringes of hairs. Young larvae are tiny, flat, and taper toward the rear. Full-grown larvae are cylindrical and about 5 mm long. The larvae feed singly, forming irregular blotchlike mines just below the upper leaf surface. A single leaf may contain several contiguous mines (fig. 42). Winter is spent in the larval stage in leaves on the ground and there are several generations per year. Injury to forest trees is of minor importance, but the beauty of shade trees may be seriously reduced.

The **gregarious oak leafminer**, *C. cincinnatiella* (Chambers), occurs throughout the same range as that of the solitary oak leafminer, and it feeds on the same

F-504082

Figure 42.—Oak leaves with the blotchy mines characteristic of attack by the solitary oak leafminer, *Cameraria hamadryadella*.

hosts. The adults and larvae of the two species are similar in appearance, but the feeding habits of the larvae differ. Larvae of this species are gregarious, forming large brownish-yellow mines, several of which may be found on a single leaf. Winter is spent in the pupal stage in leaves on the ground, and there are two or more generations per year. Heavy infestations have been reported in oak stands in the Central States, causing severe browning and premature dropping of infested leaves over large areas.

Many other species of leafminers attack a wide variety of deciduous trees in eastern America. *C. hamameliella* (Busck) mines the upper surface of witch-hazel leaves. It probably occurs wherever witch-hazel grows. The mines are circular or somewhat irregular. *C. bethunella* (Chambers) mines the leaves of oak in Delaware. *C. aceriella* (Clemens), the **maple leafminer**, produces large white mines in the upper sides of red and sugar maple leaves. *C. corylisella* (Chambers) mines the leaves of hazel in Maine. *Phyllonorycter salicifoliella* (Chambers) occurs throughout most of the United States and also in Canada. Its preferred host appears to be quaking aspen *(817)*. *P. crataegella* (Clemens) mines the leaves of apple, hawthorn, cherry, plum, and quince. Heavily infested trees become ragged and scorched in appearance. *P. lucetiella* (Clemens), the **basswood blotchminer**, mines the leaves of basswood. The mine is nearly square. *P. trinotella* (Braun) mines the undersides of the leaves of red and Norway maples. *P. robiniella* (Clemens) produces digitate mines in the upper surfaces of black locust leaves. The **aspen blotchminer,** *P. tremuloidiella* (Braun), constructs oval mines in the leaves of quaking aspen. It is occasionally quite abundant in the Lake States and Maine. *Chrysaster ostensachenella* (Fitch) forms blotch mines in black locust leaves.

Marmara fasciella (Chambers) is widely distributed, probably occurring throughout the range of its host, eastern white pine. Eggs are laid on the bark of branches of the host. Young larvae bore through the bark and construct linear mines in the inner bark. Winter is spent as a larva in the mine; pupation occurs during late

spring, and adults begin to appear in late May. Several other species of *Marmara* have been recorded mining the inner bark of twigs of balsam fir, oak, willow, and other trees *(433)*.

Phyllocnistis populiella Chambers, the **aspen leafminer**, is widely distributed in southern Canada and the Northern States. It feeds on various species of poplar, especially quaking aspen. In the Eastern States, it has been recorded as far south as West Virginia. Eggs are laid near the tips of young leaves in the spring. The larvae form tortuous mines in the leaves (fig. 43), mostly on one side of the midrib *(231)*. Noticeable infestations have been observed in Maine.

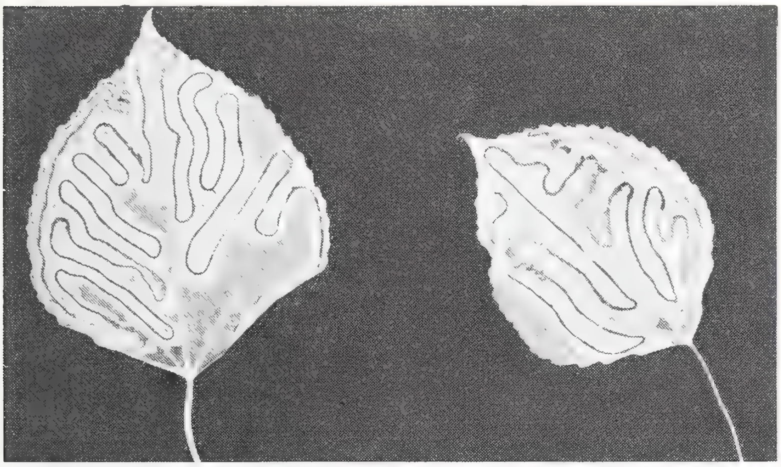

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Figure 43.—Small track mines of *Phyllocnistis populiella*, the aspen leafminer.

Phyllocnistis liriodendronella Clemens larvae mine the undersides of young leaves of yellow-poplar, and *P. magnoliella* Forbes mine the undersides of young leaves of magnolia. The mines originate near the outer margins of the leaves and continue tortuously until large portions of the upper surfaces are detached. The damaged areas have a bluish cast. *P. liquidambarisella* Chambers mines the leaves of sweetgum.

The larvae of *Parectopa robiniella* Clemens feed in the leaves of black locust, forming triangular, blisterlike mines.

Parornix geminatella (Packard), the **unspotted leafminer**, occurs throughout the Northern States, west and south to Colorado, Virginia, and Arkansas. Its hosts are apple, quince, pear, sour cherry, pin cherry, plum, and hawthorn. Eggs are laid on the undersides of the leaves, and the larvae devour all of the tissues between the upper and lower surfaces of the leaves. Four generations per year have been recorded in Virginia.

The **lilac leafminer**, *Gracillaria syringella* (F.), an introduced species, occurs in many of the Northeastern States and southeastern Canada. Its hosts are listed as lilac, black ash, privet, and euonymus. The adult has a dark-brown body and a wingspread of about 10 mm. The forewings are brownish except for six irregular transverse patches of yellow, and the hindwings are grayish brown. Full-grown larvae are pale yellowish, translucent, and about 8 mm long. Early instars feed gregariously inside the leaves and produce blotchlike mines. Later, they abandon their mines and roll or web together several leaves on which they feed from within this shelter. There are two generations per year. Injured portions of infested leaves dry up and become unsightly. Raking and destruction of fallen leaves is a good control practice.

The **boxelder leafroller**, *Caloptilia negundella* (Chambers), occurs throughout eastern America west to the Prairie Provinces of Canada and feeds on boxelder. Early instars feed within mines in the leaves. A partly grown larva vacates its mine and moves to the tip of a lobe of the leaf, which it then turns over and attaches to the lower surface with silk, thus forming a shelter. It then feeds from within the shelter. There appears to be at least two generations per year as far north as Canada. Heavily infested trees may be seriously damaged.

Caloptilia sassafrasella Chambers, the **sassafras leafminer**, feeds on the leaves of sassafras. The larvae feed first within mines. Later, they vacate their mines, move to nearby leaves, bend their tips over, and feed from inside the folds. Mature larvae vacate these folds and form split, capsulelike cases on the undersides of other leaves in which to pupate. The **azalea leafminer**, *C. azaleella* Brants, larva bends the tips of azalea leaves downward and feeds from inside the folds. Injured leaves wilt and die. *C. packardella* (Chambers) larvae mine the undersides of sugar and Norway maple leaves in the early instars. Older larvae feed on the surface of the leaves. Other eastern species of the genus and their hosts include *C. bimaculatella* (Ely) on maple, *C. stigmatella* (F.) on poplar and willow, *C. quercinigrella* (Ely) on oak, and *C. pulchella* (Chambers) on yellow birch and alder.

Family Oecophoridae
Oecophorids

This family contains a large number of moderately small moths, only a few of which are ever very injurious to trees in the Eastern United States. The larvae of most species roll, tie, or web together the leaves on which they feed. A revision of the family is available *(215)*.

Machimia tentoriferella Clemens, occurs rather commonly in the Northeastern States and southeastern Canada. Its hosts are various hardwoods such as birch, ash, maple, oak, honeylocust, mountain-ash, hickory, elm, and pin cherry. The adult is light ochreous and has a wingspread of 18 to 20 mm. The forewing is dusted with black and marked with two black discal dots, a spot of black in the fold, a broken postmedial line parallel to the outer margin, and a series of black terminal dots. The larva is green and has a large head and tapering body. It lives and feeds inside a folded leaf.

Psilocorsis cryptolechiella (Chambers) occurs in eastern Canada and the Northeastern States. The larva feeds principally as a leaftier on American beech. Other hosts include the birches, maple, and red oak. The biology in Nova Scotia is discussed *(381)*.

Full-grown larvae have reddish-brown heads, pale-green bodies, and are about 12 mm long. Eggs are laid singly on the undersides of leaves. During the first three instars, the larvae feed together and skeletonize the leaves near the veins. Older larvae usually feed singly from within the silken tubes they spin. Full-grown larvae drop to the ground and crawl under fallen leaves, where they pupate and overwinter. *P. reflexella* Clemens and *P. quercicella* Clemens occur on oaks in the Eastern States. *P. reflexella* has been observed feeding on quaking aspen in eastern Canada. It probably occurs in the Northeastern States also.

Other tree-infesting species of oecophorids and their hosts in the Eastern United States are *Agonopterix pteleae* Barnes & Busck on the common hoptree, *A. robiniella* (Packard) on black locust, *A. argillacea* (Walsingham) on willow, *A. nigrinotella* (Busck) on prickly-ash, *Bibarrambla allenella* (Walsingham) on white birch and oaks, and *Nites betulella* (Busck) on white birch and hophornbeam.

Family Blastobasidae
Blastobasid Moths

Blastobasid moths are small with long antennae. Long scales on the head often cover the face and base of the antennae. The scape of the antenna is broad and armed with a fringe of bristles, and the hindwings are narrower than the forewings. The larvae feed in the cones, nuts, and seeds of various trees; as scavengers in hollowed-out nuts or insect galls; or as predators on scale insects.

Valentinia glandulella (Riley), the **acorn moth**, feeds in acorns, hickory nuts, and chestnuts in southern Ontario and southward throughout the oak region of the Eastern and Central States. Larvae are grayish white or yellowish, with blackish marks on top.

Holcocera lepidophaga Clarke larvae feed mainly in male flower buds and flowers or among the basal scale leaves of young cones and vegetative buds of slash and longleaf pines in Florida. It has also been recorded from Massachusetts. The adult has a wingspread of 11 to 17 mm. The head is ochreous-white, with slight infuscation posteriorly; the antennae are ochreous-white with narrow, dark annulations; and the forewings are ochreous-buff. The larvae of *Zenodochium coccivorella* (Chambers) are internal parasites of female scale insects of the genus *Kermes* in Florida.

Family Coleophoridae
Casebearer Moths

About 145 species of casebearer moths occur in North America. The adults are plain, little moths with markings limited to dustings of lighter or darker colored scales. The wings are narrow and have a wingspread of 12 mm or less. The larvae of all species feed within leaf mines in the first instar. At the end of this instar, each larva constructs a portable case in which it lives thereafter. The larvae of certain species continue to feed as miners after the first instar. Without leaving the case, the larva mines in a circle or from each side of the point of entrance into the leaf. The larvae of other species feed externally in the later instars. Their cases are constructed from parts of the mined leaves and are lined with silk. They are enlarged by the larvae as needed, thus providing shelter at all times. The winter is spent as a partly grown larva in a case which is usually fastened securely to a twig or branch with silk.

Coleophora tiliaefoliella Clemens constructs a black case on basswood. *C. atromarginata* Braun occurs on southern red and swamp white oaks. Its case is black with white markings on the underside. *C. querciella* Clemens occurs on white and swamp chestnut oaks. Its case is grayish with a black patch on the top near the rear end. *C. alniella* Heinrich has been observed on beech in New York.

The **pecan cigar casebearer**, *C. laticornella* Clemens, occurs from New England to Florida and west through Texas. Its hosts are pecan, walnut, and various hickories. The adult is brownish and has a wingspread of about 10 mm. The larval case is brown, smooth, cigar-shaped, and about 6 mm long. The winter is spent as a partly grown larva in the case. Feeding is resumed in the spring on opening buds and young foliage. Damage is often serious *(484)*.

The **elm casebearer**, *C. ulmifoliella* McDunnough, an introduced species first observed in the vicinity of New York City in 1901, is widely distributed in the Northeastern States and also occurs in southern Ontario. Its hosts are English, Scotch, and various native elms. The female adult is buff, covered with gray markings, and has a wingspread of about 12 mm.

Adults appear in late July and lay their eggs on the leaves of their hosts. At first the larvae feed within mines in the leaves. Then they emerge and construct tiny cases in which they migrate to the twigs where they spend the winter. Feeding is resumed in the spring with each larva eating out a tiny circular hole in a leaf and then, without leaving its case, mining out an area between the larger veins as far as it can reach. The case is enlarged as needed to accommodate the growing larva, eventually reaching a length of 9 to 10 mm. This species is primarily a pest of shade and ornamental trees. The mined parts of leaves turn brown and, when numerous, are unattractive. Fortunately, outbreaks are usually limited.

The **larch casebearer**, *C. laricella* (Hübner), an introduced species, was first recorded in North America in Massachusetts in 1886. It now occurs throughout most of the range of tamarack in North America, west to central Minnesota and northwestern Ontario. In 1957, an infestation was also discovered on western larch in Idaho *(298)*. It is now widespread in the region of western larch. The adult is silvery to grayish brown, has narrow wings fringed with long hairlike scales, and a wingspread of about 9 mm. Full-grown larvae are about 6 mm long. The pupa is brown. This species is one of the most serious defoliators of larch in North America. Outbreaks have been occurring at about 8-year intervals in eastern Canada. Heaviest losses result from reduced growth, twig mortality, and increasing numbers of adventitious shoots. Trees completely defoliated for 2 or more consecutive years may be killed.

Eggs are deposited singly on needles in early summer and hatch in about 2 weeks. The newly hatched larva bores directly into a needle and continues to mine it until late summer. Then the larva lines a hollowed section of the needle with silk and chews the section free at both ends thereby forming a case. The remaining larval period is spent in the case, which is enlarged as needed. A single larva may mine several needles before the needles fall. Before the onset of cold winter weather, the larva migrates to an outer twig or branch to which it fastens its case, usually at the base of a bud. Several cases may be found grouped together around the bases of spurs from which new needles arise in the spring. The most serious damage is done by the large larvae as they feed on newly developing foliage during the spring. Adults emerge from late May to early July, depending on locality and season. There is one generation per year.

The larch casebearer is attacked by more than 50 species of native parasites in eastern America, but none is particularly effective in control. Two introduced hymenopterous parasites, *Agathis pumila* (Ratzeburg) and *Chrysocharis laricinellae* (Ratzeburg) are now widely distributed and are believed to be quite helpful in control. Rearing methods have been devised for these parasites *(1046)*.

The **birch casebearer**, *Coleophora serratella* (L.), an introduced species first observed in North America in Maine in 1927, is now known to occur throughout the Northeastern States and from Newfoundland and New Brunswick to southern Ontario. In the past, this insect was also called the **cigar casebearer**. Its favored hosts are paper, gray, and European white birches. Eggs are laid in July along the midribs and larger veins on the undersides of leaves. Young larvae enter the leaves and feed as miners for several days, then they emerge and construct cases in which they live and feed thereafter. Winter is spent in cases firmly attached to the bark, usually in crotches of limbs. In the spring, the larvae feed on buds and young leaves, mining as far as possible without leaving their cases. Infested leaves tend to shrivel. This species has been abundant in Quebec, New Brunswick, and northern Maine. Many stands of paper birch in New Brunswick were completely defoliated

in 1968. This insect is also a pest of apple in the Northern States, and attacks cherry, hawthorn, plum, quince, and pear as well. It is most injurious in the spring when the larvae feed on expanding foliage, flowers, fruit, and fruit stems.

The **palm leaf skeletonizer**, *Homaledra sabalella* (Chambers), feeds on many varieties of palms, particularly Canary Island date palm and cabbage palmetto, in the Southern States. It is often quite injurious in Florida. The larvae feed in groups of 35 to 100 under webs of silk on both the upper and lower surfaces of the leaf *(264)*. Eggs are usually laid in masses on the interleaf husks. There are no hibernation stages and there may be up to five generations a year. Cutting out and burning all interleaf husks and infested fronds is helpful in control.

Family Agonoxenidae
Agonoxenids

Chrysoclista linneella (Clerck), the **linden bark borer**, an introduced European species, was first reported in this country in 1928 when it was found infesting basswood trees near New York City. Other infestations were later found in surrounding parts of New York and New Jersey, and near Boston, Mass. Its current distribution is not known. Full-grown larvae are whitish with light-brown heads, and are about 6 mm long. Adults are present from late May to mid-June and are thought to lay their eggs on the branches of their host. The larvae bore into and tunnel the bark. Winter is spent in the larval stage, and pupation occurs in the spring in cells formed in the galleries close to the surface of the bark.

Family Cosmopterigidae
Cosmopterigids

Stilbosis ostryaeella (Chambers), a leafminer of ironwood, has been recorded from New York, Kentucky, Ohio, and southern Ontario. Its eggs are laid on the undersurface of leaves, near the midrib. The larvae feed in the tissues of the leaf between two lateral veins, and form blotch-type mines. Full-grown larvae vacate the mines in the fall and drop to the ground where they spin thin, loosely woven silken cocoons in the litter. Winter is spent in the pupal stage *(736)*.

Family Gelechiidae
Gelechiid Moths

Gelechiid moths are small and have narrow forewings. The outer margins of the hindwings are usually concave. The larvae of some feed in folded or rolled leaves webbed together; others feed as leafminers; still others feed in buds, seeds and cones, and roots. A few species are quite destructive.

Coleotechnites apicitripunctella (Clemens) occurs in Quebec and in the Northeastern States. Its known hosts are eastern hemlock and baldcypress. The adult is buff yellow to whitish and has a wingspread of 12 mm. The forewings are marked with blackish spots and dots, and the hindwings are fringed. The larva is greenish, sometimes with a brownish tinge, and is about 6 mm long. Adults are present from early June to mid-July, and the larvae feed for the rest of the summer and fall. They mine the leaves and web them together, forming broad, flat nests. A nest may contain six or eight mined leaves where the larvae spend the winter. Feeding is resumed in the spring, and pupation occurs in late spring or early summer. There is one generation per year. Local outbreaks occur occasionally.

Coleotechnites thujaella (Kearfott) occurs from New Jersey to New Brunswick and westward to Saskatchewan, in Canada. The larvae are leafminers on northern white-cedar. The adult is creamy white with heavy dustings of black and brown scales and has a wingspread of about 9 mm. There are three oblique blackish bands, a number of costal and terminal dots, and a shaded apical region on each forewing. Eggs are deposited from late June to early August between scalelike leaves on

growing tips. The larvae bore into the tips and mine along the twigs, causing the foliage to turn brown. Winter is spent in the larval stage in a mine, and there is one generation per year. Ornamental northern white-cedar is subject to serious injury.

Coleotechnites piceaella (Kearfott) occurs commonly from Maine to Colorado and from the Maritime Provinces to Alberta in Canada. Its hosts are white, blue, Engelmann, Norway, red, and black spruces. The adult is light gray and has a wingspread of about 12 mm. The head and thorax are pale yellow to whitish. The forewings are buff or ochreous near the base, shading to fuscous at the apex, and are marked with dark-gray, diagonal crossbands and a few conspicuous black spots. The hindwings are broad and gray with a silvery sheen; the abdomen and legs are ochreous, sprinkled with gray. Full-grown larvae are reddish to cinnamon brown and about 8 mm long.

Adults are active from June to late July, depending somewhat on season and locality. Eggs are laid singly or, rarely, in groups of two or three either between the axils of current-year needles, in insect-damaged or mechanically damaged needles, in insect-damaged cones, or in spent staminate flowers. Some also may be deposited at the base of needles or inserted between the scales of sound cones. The larvae feed as miners in healthy needles, in needles and cones damaged by other insects, in spent staminate flowers, and in dead needles on shoots damaged by late spring frosts *(802)*. Winter is spent in the larval stage, and there is one generation per year. Damage is usually not very injurious, but may be important on ornamentals.

Other eastern species in the genus *Coleotechnites* include *C. juniperella* (Kearfott) that mine the needles of redcedar and common juniper in the Northeastern States, *C. dorsivittella* (Zeller) that feeds on sweetgum, and *C. variella* (Chambers) that feeds on baldcypress. Heavy infestations of *C. variella* have killed the top 60 or 90 cm of baldcypress trees up to 6 m tall in Ohio. *C. chillcotti* Freeman is a common needleminer of longleaf pine in Louisiana. The morphology of the pupa is discussed *(94)*.

The **pine needleminer**, *Exoteleia pinifoliella* (Chambers), occurs in southeastern Canada and south to Georgia and Texas. Jack, pitch, and shortleaf pines are preferred hosts, but it has also been observed feeding on Virginia, Scotch, longleaf, loblolly, and red pines. The adult has a wingspread of about 9 mm. The forewing is reddish to golden brown and is marked by four narrow, grayish bands. The hindwings are wider than the forewings. Full-grown larvae are pinkish and about 6 mm long.

Females deposit their eggs in recently vacated, mined needles from May to July, depending on location. Young larvae vacate the old mined needles and bore into the bases of current-year needles, killing them within 2 or 3 weeks. Older larvae mine in both old and new needles, killing the apical portions beyond the entrance holes. Winter is spent in the larval stage, and there may be two or more generations per year *(418)*. Forest-grown trees are occasionally infested heavily, but are seldom injured seriously. However, heavy infestations on ornamentals or in plantations may be serious. The mite *Pediculoides ventricosus* (Newport) appears to be an effective predator in some areas. It is reported to have destroyed more than 75 percent of late instars in infestations in North Carolina *(74)*.

Exoteleia dodecella (L.), the **pine bud moth**, was discovered in the Niagara Peninsula, Ontario, in 1928, and now occurs throughout southern Ontario. As far as known, it has not yet crossed the border into the United States. Its preferred hosts appear to be Scotch and Swiss mountain pines, but several other pines such as eastern white, red, jack, and Austrian may be attacked in heavily infested areas.

Old Scotch pines, particularly those growing along roadsides, are highly subject to attack. Infestations on such open-grown trees may persist for years. Heavy infestations cause a thickening or browning of the needles, followed by branch malformation. Eventually, the needles thin out. A high proportion of the buds on young trees may be killed.

Eggs are laid on current-year and 1-year-old shoots in late July or early August. The larvae feed on the needles during the first season; the following spring they feed on the buds. Winter is spent in the third instar in mined needles *(819)*.

The **pine candle moth**, *E. nepheos* Freeman, first recorded in southern Canada in 1958, is also known to occur in Ohio. Its known hosts are red and Scotch pines and, rarely, Swiss mountain pine. The adult is small and inconspicuous and has a wingspread of less than 12 mm. Mature larvae are pale yellow with a reddish hue and are about 6.5 mm long. Winter is spent in the larval stage.

Adults are present from early July to early August in Ontario (in Ohio they may appear as early as June 1). Eggs are laid singly or, rarely, in clusters of two to four, on the sheaths of previous year's needles or, occasionally, under loose bark scales of twigs. Newly hatched larvae bore into the tips of the needles. The remainder of the summer is spent mining the needle, and winter is spent in the tunnel. In the spring, the larvae vacate their tunnels and reenter the same needles, adjacent needles, or swelling buds. Larval growth is completed in May, and pupation occurs in the flowers or shoots of the tree. There is one generation per year *(739)*.

Larval feeding stunts the growth of new shoots, giving the branches of infested pines a tufted look. Infestations in Ontario have been reported on pines from 3 to 7.6 m tall.

Anacampsis innocuella (Zeller) occurs in southern Canada and from Massachusetts to Colorado and Texas. The larva is a leafroller on poplars, willow, and cherry. The adult is ash gray or slightly darker and has a wingspread of 18 to 22 mm. A pale, wavy, transverse line crosses the forewing well beyond the middle. Behind it, the color darkens and there are three dots in the cells and two in the fold. The larva is translucent green.

Larval feeding and leafrolling begin in Ohio about the time the leaves of bigtooth aspen begin to develop. Before pupation in May or June, the larva severs the petiole of the rolled leaf, causing it and the enclosed larva to drop to the ground. Rolls containing two or more leaves tend to remain on the tree. Adults appear during the last half of June. It is believed that winter is spent in the egg stage on twigs of the host *(850)*.

Anacampsis rhoifructella (Clemens) feeds on viburnum and sumac in the Northeastern States. The adult is grayish brown and has a wingspread of 15 mm. Markings on the forewings resemble those on *A. innocuella*. Larvae are pale brown to dark brownish-red. On sumac, they live in silken galleries within fruit clusters in the spring and feed in the fruit spikes.

The **palmerworm**, *Dichomeris ligulella* Hübner, occurs in Canada and in the Northern States from Maine to Minnesota. Its hosts are various hardwoods such as apple, plum, pear, cherry, hazel, basswood, and oak. Full-grown larvae are greenish and translucent, and about 12 to 15 mm long. There is a pair of narrow, whitish lines down the back, and a wider one runs along each side.

Eggs are laid on the undersides of leaves in early spring. The larvae skeletonize the leaves in exposed positions or within folded or rolled leaves. Pupation occurs in these rolls or in ground litter. Adults appear during July or August and apparently

live until the following spring. Although most important as a pest of apple orchards, this species is capable of seriously defoliating oak during outbreaks.

The **juniper webworm**, *D. marginella* (F.), an introduced species, occurs in many Eastern and Western States and in southern Canada. Its hosts include various species of *Juniperus*, such as Irish juniper, common juniper, and eastern redcedar. The adult is brownish with white front and rear margins of the forewings, and has a wingspread of 15 mm. Full-grown larvae are light brown and from 12 to 15 mm long.

Adults are present during June and July, and deposit their eggs in leaf axils of new growth. Newly hatched larvae feed first as needleminers, entering the upper surface of the needle near the axil. Mined needles turn brown and die. Dead needles are incorporated in webbing constructed between branchlets. Larvae continue to use mined needles as protective retreats while developing. During July, larvae crawl from primary mined needles and feed on adjacent needles, eventually constructing silken tubes leading from holes in the mined needles to other nearby needles. The webbed area is expanded from July to September. Entire trees up to 2.4 m tall may be completely webbed (fig. 44). Winter is spent in the larval stage in a silken case. The larvae resume feeding in the spring, becoming full grown and pupating from mid-May to early June *(939)*. Trees grown as ornamentals or in permanent plantings may be seriously damaged by this species. Cutting and removing webbed masses of foliage is a helpful control practice.

The **redbud leaffolder**, *Fascista cercerisella* (Chambers), feeds on redbud from Delaware and Maryland to Illinois and southward. The adult is velvety black except for its white head and a white collar. The forewings are slightly bronzed and marked with three costal spots and several white terminal points. The larvae feed on leaves which they web together. There are at least two generations per year.

Battaristis vittella (Busck) is widely distributed throughout the Eastern United States and southern Canada. It has been reared from the buds of Swiss mountain pine; from the cones of Scotch, Austrian, and longleaf pines; and from galls of midges on loblolly pine. The adult has bright-red eyes, the forewings are cinnamon brown and traversed by gray bands, and the wingspread is 8 to 10 mm. Mature larvae are slender and from 4 to 6 mm long. Winter is spent in the larval stage in a tunnel in a bud or cone. Pupation occurs in the spring, and adults appear by May.

Superfamily Yponomeutoidae—Family Plutellidae
Plutellids

The plutellids loosely web leaves together. The **mimosa webworm**, *Homadaula anisocentra* Meyrick, an introduced species first reported in the United States at Washington, D.C., in 1942, is now widely distributed from New Jersey and Pennsylvania southward to Florida, Alabama, and Mississippi, and westward to Kansas and Nebraska. Its host trees are silktree and honeylocust. The adult has a wingspread of about 12 mm. The forewings are mouse gray, except for a silvery luster and a stippling of black. Full-grown larvae are pale green to dark brown, are marked with five longitudinal white lines, and are about 12 mm long. Pupae are yellowish brown and about 6 mm long. They are found in whitish, silken cocoons.

The pupae generally overwinter in the soil or in other protected places. Adults appear by June, and the female deposits her eggs on flowers or foliage, or on the bark of small branches and twigs. Egg laying continues throughout the season. First and second instars spin webs around flowers and leaves, within which they live and feed (fig. 45). Adjacent surfaces of webbed leaves may be skeletonized, turn brown, and die. Older larvae feed on the tender, terminal leaves. Pupae of this generation

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Figure 44.—Defoliation by the juniper webworm, *Dichomeris marginella*.

Courtesy Can. For. Serv., Can. Dep. Environ., Sault Ste. Marie, Ont.

Figure 45.—Webs formed by the mimosa webworm, *Homadaula anisocentra*.

are formed in the webbing of infested trees. Second-generation adults appear during late July and early August and deposit their eggs on webs formed by first-generation larvae. In heavily infested areas, the larvae of this generation may completely defoliate their hosts. Some of the second-generation larvae pupate in cocoons spun in webs on trees, and the adults appear during the fall. Other larvae move to the soil or other protected places, pupate, and spend the winter *(1276)*.

The mimosa webworm is a serious defoliator of ornamental plantings of silktree and honeylocust. The thornless variety of honeylocust is heavily attacked in nurseries. Season-long protection against attack has been obtained by the use of systemic insecticides *(319)*.

Family Yponomeutidae
Ermine Moths

The ermine moths web foliage together. The **ailanthus webworm**, *Atteva punctella* (Cramer), feeds on the foliage of ailanthus throughout the Southern States and north to New York and the Lake States. The adult is orange to brownish and has a wingspread of 25 to 30 mm. The forewings are bright yellow, and each one has four rows of round yellow spots on a blue background. The larvae feed on leaves enclosed in frail, silken webs. The **pine needle sheathminer**, *Zelleria haimbachi* Busck, feeds rather commonly on jack pine in southern Ontario. It may occur in the Lake States.

Family Argyresthiidae
Argyresthiids

Moths of this family are small, usually brightly patterned, and have rather broad wings.

The genus *Argyresthia* contains a number of leafmining species. The adults have wingspreads of about 8 to 12 mm. While at rest, their wings are folded close to the body, their front legs are extended forward, and their hindlegs are slanted upward at 45° angles.

Argyresthia freyella Walsingham is generally distributed in eastern Canada and south and west to the Middle Atlantic States and Missouri. Its hosts are redcedar and northern white-cedar. The adult is whitish and has a wingspread of about 8 mm. The forewings are golden with silvery spots and bands and a black dot at the apex of each. The larvae feed in mines that they extend along main branches and branchlets. Winter is apparently spent in the mine as a full-grown, yellowish-green to green larva, and there is one generation per year. Pupation takes place in the spring in cocoons spun on leaves or branches. Damage to ornamentals and nursery seedlings appears to be less than that caused by the related species, *A. thuiella*. *A. aureoargentella* Brower attacks northern white-cedar. It resembles *A. freyella* except that its cocoons are whiter and larger.

The **arborvitae leafminer**, *A. thuiella* (Packard), feeds on northern white-cedar throughout much of the same area as that occupied by *A. freyella*. The adult is light gray to white and has a wingspread of about 8 mm. The forewings are marked with brown and there is a black spot in the middle edge of the distal end of each. The larva is about 3 mm long. The head and cervical shield are shiny black, the body is green with a reddish tinge, and the legs and anal plate are black. Adults appear from late May to mid-July, and the female deposits her eggs in the axils of branchlets or along the edges of leaves. Newly hatched larvae bore into the leaves and feed in them as miners for the rest of the season. Winter is spent in the larval stage in the mine and pupation and adult emergence occur in the spring. Outbreaks in Maine have severely damaged forest stands of northern white-cedar. Damage to ornamentals and nursery seedlings is often serious. Heavily defoliated trees may be killed *(160)*. The habits of the species of arborvitae leafminers have been discussed *(1081)*.

Larvae of the **apple fruit moth**, *A. conjugella* Zeller, bore in the fruit of mountain-ash, serviceberry, hawthorn, apple, plum, and cherry in the Northeast. The adult is dark gray and has a wingspread of 10 to 12 mm. The forewings are dark gray, very slender, crossed by black and silver-white bands, and each bears a yellowish-white spot on the outer margin. *A. laricella* Kearfott, the **larch shoot borer**, larvae bore in the shoots of larch in southern Canada and the Lake States.

Family Sesiidae
Clearwing Moths

Members of this family are known as clearwing moths because the greater part of one or both pairs of wings are without scales, thus leaving them clear or transparent. The forewings are long and narrow, with the outer margins short and the anal veins reduced. The hindwings are somewhat broader than the forewings, and the anal areas are well developed. In some species, the two sexes are colored differently. Many species bear a striking resemblance to bees or wasps. The adults are swift fliers and are most often seen around flowers. The larvae are ivory-white and mostly unmarked. They bore in the roots and basal stalks, the trunks, or branches of trees, shrubs, and vines, or in the stems and roots of herbaceous plants. A few form galls, others are inquilines in galls, and some inhabit injured areas on the trunks or branches of their hosts. A number of species are important pests of forest and shade trees and ornamentals. The family is discussed *(345, 384, 795).*

The **hornet moth**, *Sesia apiformis* (Clerck), an introduced species first observed in North America around 1880, is now known to occur in Massachusetts, Connecticut, New York, New Jersey, Pennsylvania, and California. Its hosts are poplar and willow. The larvae bore in the roots, trunks, or large limbs. The adult is brownish black except for yellow markings on the head and sides of the thorax; it has a wingspread of 34 to 44 mm. It also has black and yellow bands on the abdomen, and brown legs. Because of its close resemblance to the giant hornet, it is known as the hornet moth. Full-grown larvae are white with reddish heads and are about 30 to 50 mm long. They excavate extensive tunnels in their hosts, causing swellings to occur. Young trees are often killed. Two years are required to complete the life cycle. The first winter is spent in the larval stage in the wood; the second, as a larva in a cocoon in wood borings in or close to the base or roots.

Sesia tibialis (Harris), the **poplar clearwing moth**, attacks poplar and willow from New York to Nova Scotia westward across the Northern States and southern Canada to the Pacific Coast and southward to California. Adults are distinguished by their black abdominal segments, of which all but the second and fourth have narrow posterior yellow margins. Full-grown larvae are 40 mm or more long. Infestations are located well down on the trunk or in the roots.

The **dogwood borer**, *Synanthedon scitula* (Harris), occurs in southeastern Canada and throughout the eastern half of the United States. Although normally a bark borer in oaks, it also attacks a wide variety of other deciduous hardwood trees, shrubs, and sometimes pine. It is often an important pest of flowering dogwood and pecan. In the South, it is commonly called the pecan borer. Abnormal growths such as woody galls, excrescences due to fungi, rusts, blight, and bruises and healing wounds are attractive as points of attack. Galls, such as those produced by the cynipid *Callirhytis cornigera* (Osten Sacken) on black and pin oaks, sometimes occur in the thousands on a single tree, and nearly every one will be infested by this borer *(384).*

The adult is a small, blue-black moth with yellow-banded legs and yellow stripes on segments two and four of the abdomen. The wings are transparent with blue-black margins, and the wingspread is from 14 to 20 mm. The larvae are whitish with brown heads and are up to 14 mm long.

Eggs are laid from late spring to midsummer on rough bark or around wounds. The larvae enter the bark through openings and feed in the cambial area. Infested areas are sometimes up to 61 cm or more in length and may contain up to 50 larvae each on the larger trees. A single larva can kill a dogwood 10 cm in diameter in 1

year. There are one and possibly two generations per year, depending on locality. Keeping the bark smooth, especially at the base of branches, has been recommended for control on dogwood *(1239)*.

The **rhododendron borer**, *S. rhododendri* (Beutenmüller), attacks rhododendron and sometimes laurel and azalea in the Atlantic Coastal States. The adult is blackish, except for various white and yellow markings, and has a wingspread of 10 to 15 mm. Mature larvae are up to 15 mm long. The winter is spent as a full-grown larva in the stem of its host. Pupation occurs in the spring, and the adults appear during May and June. Eggs are deposited on the bark, and the larvae bore into the stems, causing ugly scars and sometimes killing large branches and small plants. Cutting out and burning infested parts of plants and the use of two to three well-timed insecticide applications are recommended control practices *(908)*.

The **maple callus borer**, *S. acerni* (Clemens), is widely distributed in southern Canada and throughout the Eastern United States south to Florida. Its hosts are sugar and red maples. The adult is amber colored and has a wingspread of 20 to 25 mm. The head is orange-yellow and there is a red tuft of hairs at the posterior end of the yellow-banded abdomen. Full-grown larvae are white and from 14 to 19 mm long.

Adults appear in May and June and deposit their eggs in roughened places on the trunk, preferably on or near wounds. The larvae bore through the bark and into the sapwood. Slightly wounded trees are often severely damaged. Winter is spent in the larval stage and pupation occurs in the spring. Just before it changes to an adult, the pupa wriggles part way out of its burrow. When the adult emerges, the cast pupal skin is left sticking out of the bark. There is one generation per year. Smoothing roughened bark areas, removing borers from under the bark in the spring, and painting wounds are recommended control practices. The southern form attacks silver maple in Florida and Georgia.

The **pitch mass borer**, *S. pini* (Kellicott), occurs in eastern Canada and the Eastern United States southward to Georgia and Tennessee and westward through the Great Lakes region. Its preferred host apppears to be eastern white pine but it also attacks Austrian and Scotch pines and spruce. The forewings are blue-black, with a metallic-green luster, and have a wingspread of 25 to 30 mm. There is an orange band on the fourth abdominal segment and a tuft of orange scales at the tip of the abdomen. Mature larvae are white to pink and 25 mm long.

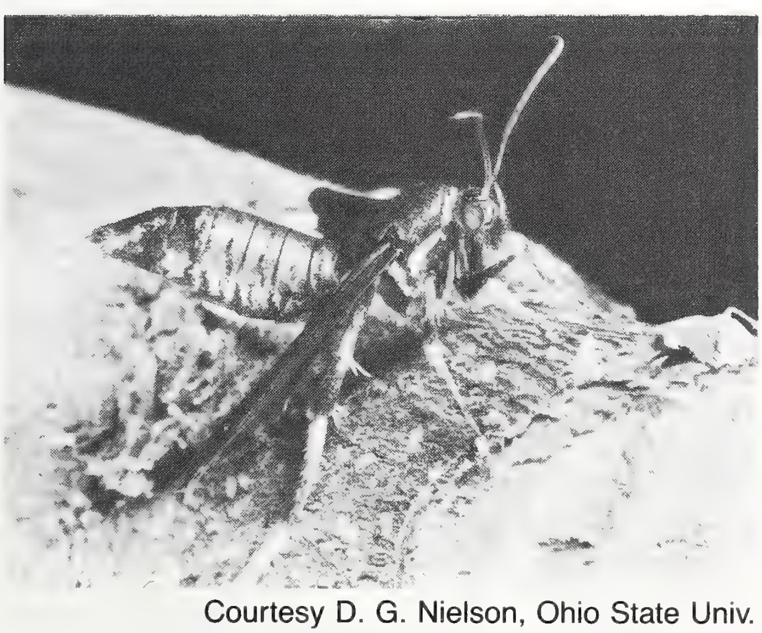
Eggs are deposited on the bark during June and July, usually near a wound, on old scars, or just below a branch. The larvae bore in the inner bark and sapwood, excavating more or less transverse tunnels, and cause copious flows of pitch. This pitch accumulates in masses 8 to 10 cm in diameter at the entrance hole. Pupation occurs in the pitch mass, and when the moth emerges the empty pupal case is left sticking out of the mass. The life cycle requires 2 to 3 years. Although not a killer of trees, this species causes some lumber degrade as a result of its activities. No practical control methods are known for use on forest-grown trees. Borers in shade, ornamental, or park trees may be removed with a knife.

Several other species of *Synanthedon* also occur in eastern North America. *S. geliformis* (Walker) is a bark borer in dogwood and pecan. It also infests cynipid galls on the trunks and branches of oaks, and diseased and injured tissues of various other plants. The **apple bark borer**, *S. pyri* (Harris), attacks apple, hawthorn, serviceberry, and mountain-ash. The larvae excavate shallow, tortuous tunnels in and beneath the bark of trees usually injured by storms and disease, causing the

bark to blister and peel. The **lesser peachtree borer**, *S. pictipes* (Grote & Robinson), breeds in peach, American plum, and in fungus growths on American plum. It is a major pest of peach. *S. viburni* Engelhardt larvae bore under the bark of viburnum, preferably in injured areas or galls. *S. acerrubri* Engelhardt is a bark borer in maple, preferably in branches and often in wounds and scars caused by other insects. *S. sapygaeformis* (Walker) has been recorded infesting woody galls in oaks in Florida. *S. castaneae* (Busck) bores in the trunks of American chestnut, preferably in bruised areas. *S. rubrofascia* (Henry Edwards) larvae excavate long, sinuous tunnels in the bark of tupelo from Maryland to Florida. Injuries and healing wounds on well-matured trees are preferred. *S. sigmoidea* (Beutenmüller) attacks low-growing willows in bays, along streams, and in depressions in sand dunes of coastal and lake regions. Infestations are often heavy. *S. proxima* (Henry Edwards) larvae bore in the branches and exposed roots of low-growing willows in moist or shady locations. *S. bolteri* (Henry Edwards) also attacks low-growing willows.

The **persimmon borer**, *Sannina uroceriformis* Walker, occurs from southern Maryland to Kansas, Texas, and the Gulf Coast and feeds as a larva in the solid wood of the base and taproots of persimmon. The adult is mostly bluish black and has a wingspread of 28 to 32 mm. Full-grown larvae are up to 30 mm long. Trees growing in cutover areas and in hedgerows are particularly subject to infestation. Young trees in nurseries are also damaged seriously at times. The life cycle requires 2 or 3 years.

The **lilac borer**, *Podosesia syringae* (Harris) (fig. 46), occurs from Texas and Saskatchewan east throughout the United States and southern Canada. It attacks lilac, ash, privet, and other trees and shrubs of Oleaceae. The adult has a wingspread of 26 to 28 mm. The species is polymorphic with several distinct adult morphs varying from dark brown sometimes with chestnut-red markings to light brown and yellow to distinct yellow banding of the abdomen *(345, 1006)*. The larvae bore into trunks and branches, excavating galleries up to 15 cm long and causing nursery cull, decline and mortality in shelterbelts, and degrade in timber stands. Winter is spent in the larval stage, and there is one generation per year. Woodpeckers and parasites are the major natural controls. Cultural practices that avoid bark wounds and maintain good tree vigor help to minimize losses. Chemical control is also effective.



Courtesy D. G. Nielson, Ohio State Univ.

Figure 46.—Adult of the lilac borer, *Podosesia syringae*.

The **banded ash clearwing**, *P. aureocincta* Purrington & Nielson *(1006)* (fig. 47), is known from New York south to Florida and west to Oklahoma. It has been reared from green and white ashes and probably attacks other *Fraxinus* spp. The adult is mostly brownish black but can be distinguished from the lilac borer by a narrow, orange-yellow, partial band on the fourth abdominal segment. Also, the eggs are darker, slightly larger, and have a smoother surface than those of the lilac borer. It is particularly destructive to ornamental plantings and to trees grown for timber. However, populations are more scattered than those of the lilac borer.

Courtesy D. G. Nielson, Ohio State Univ.

Figure 47.—Adult of the banded ash clearwing, *Podosesia aureocincta*.

Paranthrene simulans (Grote) occurs throughout the Eastern United States west to Texas and in eastern Canada. It attacks trees in both the red and white oak groups, but host preference varies with region. In the Gulf States it shows a decided preference for trees more than 30 cm d.b.h. in the red oak group, especially Nuttall and cherrybark oaks *(1133, 1135)*. In the Northeast, injury is greatest in nursery stock, saplings, and young trees in both the white and red oak groups. Moths emerge in June and July and deposit eggs in bark crevices on the lower trunk (fig. 48). The larvae bore through the bark and into the wood. Here they excavate galleries up to 9 mm in diameter and 10 cm long. For the first 3 to 5 cm the gallery slopes upward, then it continues straight up. The life cycle requires 2 years. Damage includes nursery cull, entryways for decay fungi, and degraded butt logs. Open-grown trees are most susceptible, thus populations can be minimized by maintaining well-stocked stands, preventing bark injuries, and removing or treating brood trees.

Paranthrene dollii (Neumoegen) bores in the base and root-collar area of young cottonwoods and black willow in the Deep South. The adult is brown with dark wings and yellow crossbands on its abdomen and has a wingspread of about 37 mm. Eggs are laid in bark crevices. The larvae bore in the wood and pith, constructing open tunnels up to 15 cm long. Heavily infested trees are weakened and subject to windbreakage. Damage is often severe in cottonwood nurseries and plantations in the Deep South where losses average 12 percent cull in nursery stock *(1132)*. There is one generation per year.

F-519923, 519922

Figure 48.—Adult and larva of *Paranthrene simulans*.

Paranthrene tabaniformis (Rottemberg) larvae bore into the branches and terminals of young cottonwoods, weakening them and causing some to break. There are one or two generations per year.

Family Choreutidae
Choreutids

The **apple-and-thorn skeletonizer**, *Eutromula pariana* (Clerck), an introduced species first recorded in New York State, is now known to occur in Virginia west to Indiana, and north to southern Canada. The larva feeds mostly on the leaves of apple, pear, and hawthorn but mountain-ash, birch, willow, plum, and sour cherry are also attacked. The adult is dark reddish-brown with a purplish tinge and has a wingspread of 12 mm. The forewings are often marked with faint, pale bands and wavy, black lines. Three or four white spots are usually along the costal margin. Full-grown larvae are yellowish green with prominent black tubercles and are about 12 mm long.

Young larvae skeletonize the undersurfaces of the leaves under loose webs. Older larvae move to the upper surfaces and draw the opposite sides of leaves together with silk. They feed inside the fold, consuming everything but the lower epidermis and larger veins. Damaged leaves curl, turn brown, and fall by early September. Pupation occurs in cocoons spun in the angles or folds of leaves, on weeds or other objects, and even in cracks of buildings. There are three and possibly four generations per year.

Family Cossidae
Carpenterworm Moths

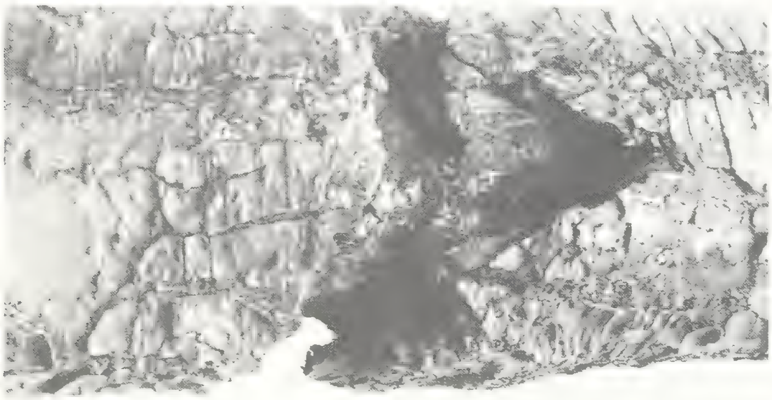
Carpenterworm moths have fairly heavy, spindle-shaped bodies, and narrow, pointed wings. The larvae excavate large galleries in the wood of trees, often causing serious injury.

The **leopard moth**, *Zeuzera pyrina* (L.), an introduced species, is known to occur from the Philadelphia area to northern Massachusetts. Its favored hosts are

elm, maple, ash, beech, walnut, oak, chestnut, poplar, willow, apple, pear, and plum, but it will attack scores of other species. The female is heavy-bodied and has a wingspread of 62 to 75 mm. Full-grown larvae are about 50 mm long. The body is usually pale yellow but may have a pinkish tinge. It is also sparsely hairy and dotted with brown or black tubercles.

Adults are present from late spring until fall. Eggs are deposited either singly or in small groups in bark crevices. Young larvae bore directly into twigs, branches, or the trunk and feed in the heartwood. When a larva becomes too large for a twig or branch, it vacates it and migrates to a larger one. As the larva feeds, it pushes chips, matted excrement, and frass to the outside through the entrance hole. Pupation takes place within the tunnel, and the life cycle requires 2 years *(612)*.

The leopard moth may cause considerable damage to its host. Damaged twigs wilt and break off, small branches break and hang down, larger branches are girdled (fig. 49) and may break in the wind, and small seedlings are killed. Ugly scars appear on the trunks of large trees where the bark dies and splits over wounds. The removal and destruction of infested twigs, branches, and heavily infested trees is a recommended control practice. Borers in valuable shade trees can be killed by probing their tunnels with flexible wires.



Courtesy Conn. Agric. Exp. Stn.

Figure 49.—Elm branch nearly severed by larvae of the leopard moth, *Zeuzera pyrina*.

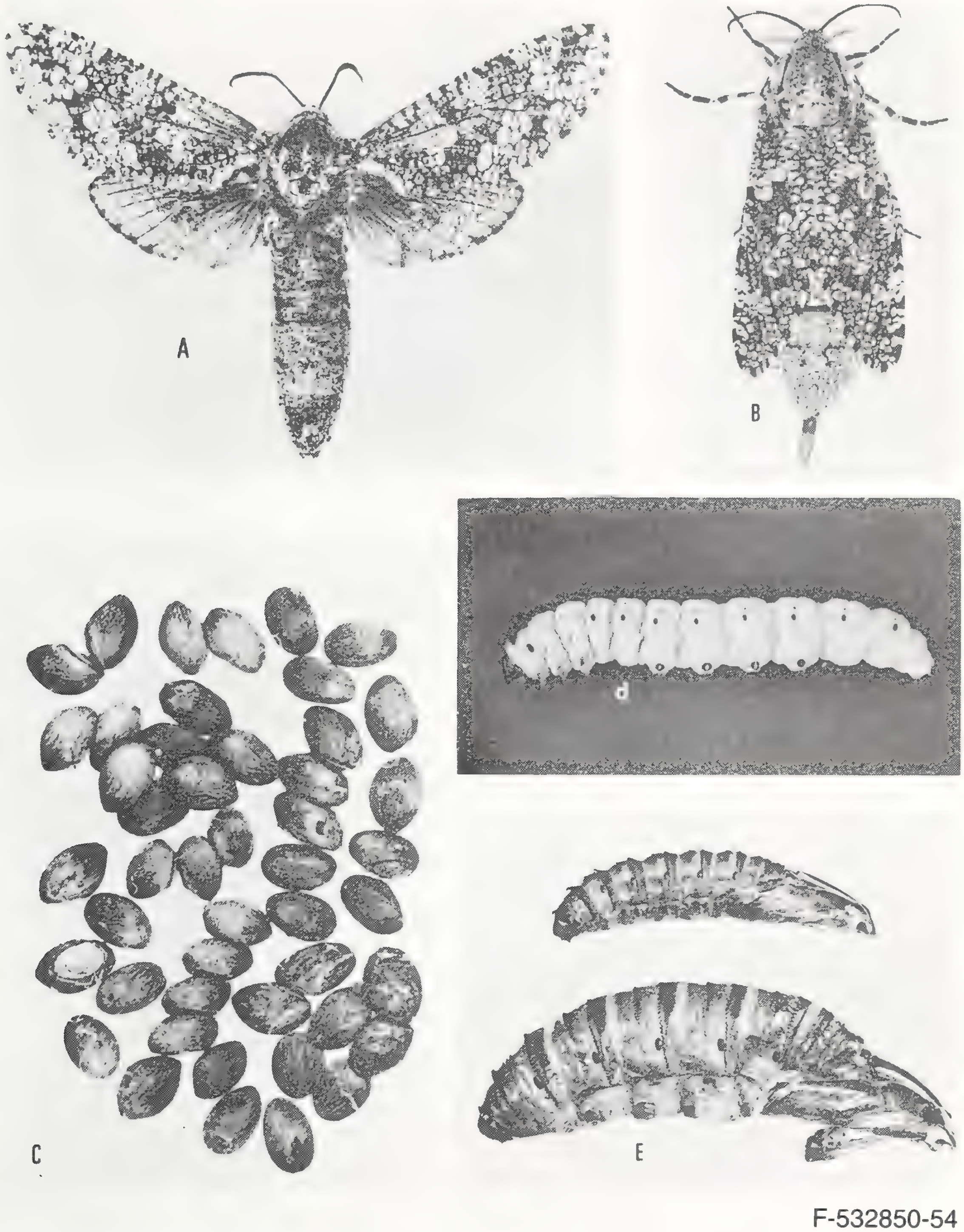
The **pecan carpenterworm**, *Cossula magnifica* (Strecker), occurs throughout the Southern States. Its hosts are pecan, oak, and hickory. The adult is grayish with brown markings and has a wingspread of 37 mm. Full-grown larvae have pinkish bodies sparsely clothed with short, fine hairs and are about 37 mm long.

Adults appear in May and June and deposit their eggs on the bark of small twigs. Newly hatched larvae bore into the twigs and tunnel in the pith. Later, they emerge and migrate to larger branches or the trunk where they enter and excavate tunnels up to 8 cm long. Frass is extruded through holes that are about 6 mm in diameter in the trunk; it can usually be found in small heaps at the base of infested trees. Winter is spent in the larval stage, and pupation occurs in the tunnel in the spring. There appears to be one generation per year *(135)*.

Acossus centerensis (Lintner), the **poplar carpenterworm**, and *A. populi* (Walker), the **aspen carpenterworm**, also occur in the Eastern United States. *A. centerensis* bores in poplars from New Jersey to North Dakota. *A. populi* is found sparsely in poplars and cottonwoods from coast to coast.

The **carpenterworm**, *Prionoxystus robiniae* (Peck) (fig. 50), is widely distributed in the United States and southern Canada where it breeds in various

hardwoods. In the Eastern and Southern States, the oaks, particularly those of the red oak group, are most heavily damaged. In the Prairie States, green ash is the chief host. Other hosts are black locust, elm, maple, willow, cottonwood, and occasionally fruit trees and ornamental shrubs *(540)*. The adult is dark, slightly mottled, stout-bodied, and has grayish black hindwings. The female is lighter colored and considerably larger than the male and has a wingspread of 75 mm. The posterior half of the hindwing of the male bears a large yellowish to orange spot with a black border. Full-grown larvae are greenish white, nearly naked, bear simple setae, and are 50 to 70 mm long. The head is shiny brown and armed with powerful, nearly black mandibles. The thoracic legs are yellowish and three-jointed, and each bears a curved, pointed tarsal claw.



F-532850-54

Figure 50.—The carpenterworm, *Prionoxystus robiniae*: A, adult male; B, adult female; C, eggs; D, larva; E, pupal cases.

Carpenterworm moths begin to appear in early April in the South, the last week of May in the Central States, and the first week of June in more northerly regions. The female deposits as many as 450 to 800 eggs in groups in bark crevices, near wounds, or under vines, lichens, or moss. Young larvae bore directly to the inner bark or enter it through openings, then bore into the wood, their tunnels angling upward in the sapwood and straight upward in the heartwood. Feeding may be finished in 1 year in the Deep South but may continue for 3 or 4 years in the North. Tunnels are kept open and enlarged as needed by the growing larvae; eventually tunnels may reach a diameter of 18 mm and a length of 300 mm. Mature larvae line their tunnels with loose, silky, yellowish-brown webs. Pupation occurs at the upper end of the tunnel. Before completing its transformation to an adult, the pupa wriggles to the mouth of the tunnel and continues until its head and thorax are protruding. Even after the adult has formed and departed, the pupal case usually remains in place, sticking out of the opening.

Carpenterworms seldom kill trees outright, although heavily riddled small trees may be broken off by the wind. Open-grown trees, or trees growing on poor sites such as dry ridgetops or ridge slopes, are especially subject to attack and damage. The greatest damage results from the degrade of lumber cut from infested trees. The overall value of rough-cut, oak lumber may be reduced by as much as 15 percent. Borer-caused losses, mostly carpenterworm, in oaks cut in the Ozark National Forest, Ark., and updated to 1980 lumber prices amounted to $42 per 5.7 cubic meters *(1131)*.

Woodpeckers, other birds, and spiders destroy large numbers of carpenterworms and are among the most important natural controls. Insect parasitism is inconsequential. Fungi and other disease pathogens kill some larvae. Cultural practices that promote tree vigor, recognize and remove brood trees, and minimize bark injuries will help to reduce losses in the forest. Shade trees can be protected by painting injuries with wound dressing. Larvae in small trees can be killed by probing their tunnels with a wire. Insecticides applied at the time of oviposition and egg hatch can be used to protect high-value trees.

The **little carpenterworm**, *P. macmurtrei* (Guérin), a species very similar to the carpenterworm, is widely distributed in eastern Canada and the Eastern United States. The larvae are borers in oaks, and their habits are similar to those of the carpenterworm. They spend their first summer in the outer layers of bark and the second in the sapwood. During the third summer, they bore in the woody part of the tree, making a labyrinth of crossing and recrossing tunnels. The third winter is spent in the pupal stage in the tunnel. This species attacks all parts of the tree more than 25 mm in diameter, and trees infested continuously become badly honeycombed. Fortunately, infestations are usually local.

Family Tortricidae—Subfamily Olethreutinae
Olethreutine and Leafroller Moths

This subfamily contains a large number of economically important species of forest insects *(1004)*. Several are particularly important as pests in nurseries and plantations. The larvae differ widely in their feeding habits. Some feed by boring into the buds, twigs, stems, roots, seed, or fruit of their hosts; others, as leafminers, feed on the foliage from within folded leaves or on the exposed surface. Many adults and larvae of North American species are described *(551, 552, 792, 793)*.

Episimus argutanus (Clemens) is widely distributed and feeds as a leafroller on sumac, poison-ivy, witch-hazel, and various other shrubs. The adult has a wingspread of about 13 mm and is dull reddish or grayish brown, mottled with darker

colors. Each larva lives in a rolled leaf or between two leaves fastened together with silk. There are two or more generations per year.

The **spruce needleminer**, *Endothenia albolineana* (Kearfott), occurs from coast to coast in southern Canada and from Maine to North Carolina, Colorado, and Idaho in the United States. Its hosts are white, Norway, Engelmann, Colorado blue, and black spruces. The adult is dark brown and has a wingspread of about 13 mm. The forewings have three irregular, transverse, broken, grayish-white bands. Its biology has been studied *(1188)*.

Adults are present from mid-May to mid-June. Eggs are deposited so that they overlap in a single row on the undersides of needles in groups of 2 to 12 eggs each. Young larvae are gregarious and bore into the bases of old needles, hollowing them out. Older larvae feed singly. Shortly after beginning to feed, the larvae construct nests composed of dead needles and frass which are held together by fine silk strands. As the larvae develop, their nests are continually enlarged. Winter is spent in the larval stage in the nest. Feeding is resumed on adjacent needles in the spring. Pupation takes place in silken cocoons within the nest during late spring or early summer.

The spruce needleminer is most important as a pest of ornamental spruce, but it also occasionally causes serious defoliation in forest stands. The presence of webs on ornamentals reduces their esthetic value. This can be largely prevented by handpicking or washing the webs from the trees before the buds break in the spring. Webs washed to the ground should be picked up and burned.

Evora hemidesma (Zeller) feeds as a leafroller on alder, poplar, and willow in southern Canada, and in the Eastern States from Maine to Virginia and Kentucky. The adult is reddish brown with a darker median band on the forewing and has a wingspread of about 15 mm. Full-grown larvae are dark green to almost black, sparsely hairy, with light-colored tubercles and light-brown heads, and are about 18 mm long. Larvae are present from May to July.

The **European pine shoot moth**, *Rhyacionia buoliana* (Denis & Schiffermüller) (fig. 51), an introduced species first recorded in North America on Long Island, N.Y., in 1914 *(178)*, is now widely distributed in the Northeastern States and southern Canada. Outlying infestations also occur in Washington, Oregon, and British Columbia. Its hosts include Scotch, red, Austrian, Swiss mountain, Japanese red, Japanese black, ponderosa, eastern white, jack, pitch, longleaf, and Virginia pines *(853, 998)*. Red, Swiss mountain, Scotch, and Austrian pines are most heavily attacked in the Eastern United States, especially red and Swiss mountain. The adult moth is rusty orange-red and has a wingspread of about 20 mm. The forewings are marked with several irregular, forked, silvery crosslines; the hindwings are dark gray, and the legs are whitish.

Adults appear in late spring and fly at dusk. They lay eggs singly or in groups of 2 to 10 on the bases of buds, on needle fascicles and twig tips, or on the bark of new and old shoots. Newly hatched larvae spin resin-coated, tentlike webs between needle sheaths and the stems of current-year growth, then they bore through the sheaths and mine the bases of the needles. About midsummer, the larvae move to buds and construct new resin-coated webs. At first these webs glisten brightly, then they solidify into yellow-white masses. Feeding ceases in August. Winter is spent in the larval stage in a feeding tunnel in or near a bud. When activity is resumed in April, the larvae move to undamaged buds and new shoots, construct new tents, and resume feeding. During this period, a single larva may feed on more than one bud

F-493841, 493467

Figure 51.—European pine shoot moth, *Rhyacionia buoliana*: A, red pine tip with solidified resin mass broken open to show partly grown larvae; B, red pine stand badly damaged by the shoot moth. Note spiked and bushy tops.

or shoot. Larvae reach maturity in May, and pupation occurs inside the burrow in late May or June. From 2 to 3 weeks later, the larva works its way out of its chamber. There is one generation every 12 months, but occurring in 2 consecutive years.

The most important and permanent damage to trees results from spring feeding. The killing of terminal and lateral buds results in dead, spike tops. The development of adventitious buds below this dead portion often causes the formation of dense, bushy growth the following season. The killing of the terminal bud and the development of several lateral buds into competing leaders results in forked stems. Shoots weakened by larval tunneling may fall over, but continue to grow. This results in the formation of crooked trunks and branches called "post horns." All open-grown young trees of susceptible species below a height of 6 to 8 m are subject to attack and damage. Taller trees or trees growing in closed stands are usually not seriously damaged. Also young trees having adequate soil moisture during early summer are not damaged; apparently the needlemining larvae are "pitched out." In Ontario this insect often destroys second-year pine cones on young trees and on the lower branches of larger trees *(760)*.

Climate is an important factor affecting the distribution and abundance of the European pine shoot moth. Overwintering larvae are killed by temperatures colder than about $-29°$ C. Warm, dry summers followed by mild winters permit maximum survival. Rate of tree growth is also important as damage is usually most severe on slow-growing trees. Introduced and native species of parasites normally destroy about 10 percent of the population. Several species of parasites introduced to North America have become established, and two of these species, *Orgilus obscurator* (Nees) and *Lypha dubia* Fallén, appear to be most successful. References are available for more complete information on arthropods attacking *Rhyacionia* spp. *(526, 788, 1184, 1363)*.

The planting of susceptible pines on good sites, "snow-depth pruning," and Christmas tree shearing are helpful in reducing damage *(852)*. Fumigation in the spring has provided a degree of control on seedlings and larger ornamental specimens *(197)*.

Many reports have been issued on the biology, ecology, and control of the European pine shoot moth. In addition to those cited in preceding paragraphs, there

are several others that are of special interest *(452, 500, 541, 548, 856, 858, 992, 1206)*.

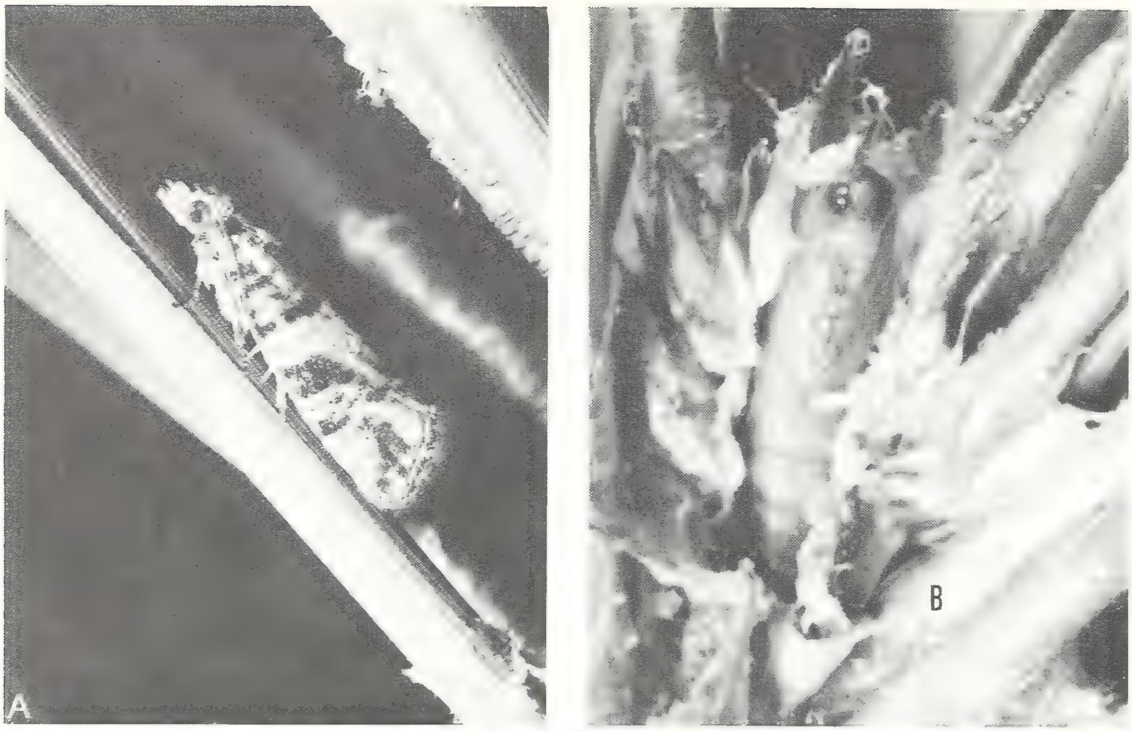
Rhyacionia adana Heinrich has been recorded from Massachusetts, Pennsylvania, Virginia, Michigan, Wisconsin, Ontario, and elsewhere *(998)*. Red, jack, and Scotch pine seedlings usually under 1 m tall in nurseries, plantations, and natural stands and the lower half of trees up to 8 m tall are attacked. The adult has a wingspread of about 16 mm. The forewing has the outer third red and the remainder gray with four pairs of grayish-white vertical bars.

In Ontario, eggs are laid between needles just above the needle sheath of the needle fascicle. Young larvae spin silken cases between two old needles just above the sheath. Then they enter the needles and mine toward the tip. Later, after new needle growth has begun, they enter and mine the developing shoots. Several larvae may inhabit a single shoot and riddle it with their tunnels. Then they vacate the shoot and move to and destroy the buds. Full-grown larvae crawl down the stem and pupate in cocoons cemented to the stem below the soil surface. There is one generation per year *(820)*. Serious damage has been recorded in red and Scotch pine plantations in Canada and the Lake States. Pole-volume yields have not been found to be seriously affected, however *(860)*.

The **pitch pine tip moth**, *R. rigidana* (Fernald), occurs from Florida to Texas and north to Missouri, New York, and Maine *(998)*. It feeds on pitch, Corsican, Virginia, red, Scotch, loblolly, and slash pines. The adult is similar to the adult of the Nantucket pine tip moth, but is slightly larger and more colorful. The forewings are silver-white with crossbands of silver-white scales, and the hindwings are silver-gray. Damage is also similar to that caused by the Nantucket pine tip moth. Pitch pines up to 40 cm in diameter may be infested.

The **Nantucket pine tip moth**, *R. frustrana* (Comstock) (fig. 52), is widely distributed in the Eastern, Central, and Southern States, and elsewhere *(998)*. Its hosts include nearly all species of pines growing within its range; the only exceptions are longleaf and eastern white pines *(1366)*. Slash pine is also somewhat resistant, but is occasionally attacked. In the South and Southeast, loblolly and shortleaf pines are preferred; in the Northeast and Middle Atlantic States, pitch, Virginia, and Scotch appear to be favored; and in the Central States, shortleaf is attacked most heavily. The adult has the head, body, and appendages covered with gray scales. The forewings are marked with irregular brick-red and coffee-colored patches, the patches being separated by irregular bands of gray scales; the wingspread is about 12 mm.

Winter is spent as a pupa within the injured tips of the host. Adults begin to appear on warm, sunny days in early spring—as early as January in the Deep South. Egg laying begins in a few days, during dusk and darkness. The eggs are deposited on new or old-growth needles, in the axils of needles and stems, on developing tips, or on buds. Newly hatched larvae wander about the shoots looking for suitable feeding sites. Soon, they construct delicate webs in axils formed by developing needles and stems. Then the larva bores into a needle sheath and feeds on the needle, which is then severed. Second instars spin new and larger webs between buds, or between buds and needles; they feed in the buds. When a bud is consumed, the larva moves to another bud on the same or a different shoot. Eventually, the connective tissue of the tip is severed, and the damaged portion turns brown. The larva continues to feed within the shoot and bud. Once having consumed the bud, it bores down the center of the stem. The larval period lasts for 2



A, F-531246; B, F-532848

Figure 52.—Nantucket pine tip moth, *Rhyacionia frustrana*: A, adult; B, pupa in loblolly pine tip.

to 4 weeks. Toward the end of this period, the larva constructs a webbed cell within the shoot in which it pupates. In the Deep South, there are three or more generations per year *(97)*. In Pennsylvania and Ohio, there are only two per year.

The Nantucket pine tip moth is a major pest of young pines in the Eastern United States. During recent years, it has become increasingly abundant and destructive as a result of the establishment of large areas of pine plantations and seed orchards. Damage by this insect retards height growth, causes crooks or forks in main stems, reduces cone crops, and, occasionally, results in the death of the tree. Attacks are generally restricted to trees less than 4.5 m in height and are most severe in young plantations, but severe attacks on commercial-size trees have also been reported. This species causes serious losses of flowers and conelets of shortleaf pine in seed orchards *(362)*.

At least 60 species of parasites of the Nantucket pine tip moth have been recorded *(1363)*, but they rarely provide satisfactory control. Damage can be reduced by limiting the planting of susceptible pines to sites to which they are well adapted. Close spacing and planting under an overstory may also be helpful.

Rhyacionia bushnelli (Busck), the **western pine tip moth**, occurs from the Dakotas and Nebraska south to Kansas and New Mexico east to Missouri. Its preferred hosts are ponderosa, red, jack, and Scotch pines. Infestations have been particularly severe in pine plantations in Nebraska *(307, 497)*. The adult is indistinguishable from those of the Nantucket pine tip moth, but it is believed that *R. bushnelli* is a distinct species because of its overwintering habit and size *(998)*. There is one generation per year in the Dakotas, one to two per year in Nebraska, and an additional one southward *(798)*.

In 1925, *Campoplex frustranae* Cushman, a common parasite of the Nantucket pine tip moth in the East, was liberated in infested plantations in the Nebraska National Forest. It became established immediately and increased rapidly. By 1930, parasitism at the original liberation point had reached 80 percent. Unfortunately, the

southwestern pine tip moth, *R. neomexicana* (Dyar), which the parasite also attacks but in which it is unable to develop, increased very rapidly in the area about this time, and parasitism of *R. bushnelli* declined. This may have happened because the parasite deposited too many of its eggs in *R. neomexicana*.

The **subtropical pine tip moth**, *R. subtropica* Miller, occurs throughout the range of slash pine in the South *(998)*. Slash pine is the preferred host, but longleaf, loblolly, and Caribbean pines are also attacked. South Florida slash pine is fairly resistant. Heavy infestations have been recorded in Florida where typical slash pine has been planted south of its range, whereas naturally regenerated slash pine seedlings have rarely been infested. Serious losses of grafted slash pine scions in tree improvement programs have been incurred.

Rhyacionia sonia Miller has been recorded in Ontario, Michigan, and Manitoba. Its host is jack pine. There is one generation per year and it overwinters as a pupa beneath trees. Superficially, the adult is similar to that of *R. aktita* Miller, a species occurring on the Coastal Plain from Maine to Texas *(998)*. The hosts of *R. aktita* are pitch, loblolly, and slash pines. It overwinters as a pupa in infested tips. Both species have been mistaken for *R. frustrana* from which they differ structurally in the adult stage.

Extensive studies of *Rhyacionia* pheromones indicate the utility of such compounds for surveying for *Rhyacionia* and other purposes *(99)*.

The **pitch twig moth**, *Petrova comstockiana* (Fernald), occurs from Maine to North Carolina and west into the Central States. Its hosts include the hard pines, but pitch pine is preferred in the Midwest. The adult is reddish brown with gray mottlings and has a wingspread of about 19 mm.

In Ohio, eggs are deposited on twigs during May and June. The larvae bore into and downward in the twigs for distances from 8 to 10 cm, and pitch masses form over the entry holes (fig. 53). Winter is spent as a larva under the pitch mass. Development is resumed in May, and pupation occurs under the mass. There is one generation per year. Damaged twigs break off, leading to deformation of infested trees. The braconid *Agathis pini* (Muesebeck) has been a major factor in control *(859)*. A similar moth, *P. taedana* Miller, attacks loblolly pine throughout the South *(854)*.

F-519519

Figure 53.—Larva of the pitch twig moth, *Petrova comstockiana,* in a red pine twig. Pitch mass covers the opening to the larval gallery.

Petrova pallipennis McDunnough feeds on jack pine in the Lake States and southern Canada. The larvae feed in and hollow out the terminals and adjacent lateral buds. Winter is spent as a larva in the large central bud. Feeding is resumed about mid-May and pupation occurs in the bud in early June. Damage to terminals and lateral buds results in the death of an entire whorl, causing crooked stems and "stag-headedness."

The **northern pitch twig moth**, *P. albicapitana* (Busck), occurs in all parts of North America where jack pine grows naturally. Scotch and lodgepole pines are also attacked. The adult is reddish brown with grayish patches on the forewings, and has a wingspread of about 18 mm.

Young pines from 0.3 to 1.5 m tall are most heavily infested. Smaller ones are not attacked and taller ones are rarely injured, although signs of attack may be seen in trees up to 9 m tall. Larvae feed singly under masses of pitch, about 2 cm in diameter, generally at an internode or fork. As they develop, their feeding may be extended almost to the pith. Two years are required to complete the life cycle, and winter is spent in the larval stage. Pupation occurs under the pitch mass.

When an attack occurs at the base of a growing terminal, the shoot may be girdled and killed, or the terminal may survive as a weakened, crooked trunk. Damage in jack, Scotch, and lodgepole pine plantations may be severe. Areas planted entirely during a 1- or 2-year period suffer much less damage than areas planted in small blocks over a period of several years *(1215)*.

Petrova houseri Miller attacks shortleaf pine from Ohio south to Florida *(854)*. The adult is dark gray with light- and dark-brown areas and has a wingspread of about 15 mm. Before its description as a new species *(851)*, its damage had been attributed to the pitch twig moth. The larvae feed in the inner bark of current shoots, usually girdling them. Pitch blisters, which form over the entrance holes, average about 1.3 cm in diameter. Usually, there is only one blister per shoot, and it is situated away from a branch node. Toward the end of summer, the larva bores down to the pith where it spends the winter. Activity is resumed in the spring, and the larva tunnels toward the base of the shoot for a distance of about 2.5 cm. Pupation occurs beneath the blister. There is one generation per year. Infested shoots usually turn reddish brown, die, and eventually break off. The braconid *Agathis pini* (Muesebeck) is an important parasite of the species.

The **eyespotted bud moth**, *Spilonota ocellana* (Denis & Schiffermüller), an introduced species, occurs from coast to coast in the Northern States and southern Canada and south to North Carolina. Its hosts are hawthorn, larch, laurel, oak, and several species of fruit trees. The adult is dark, ashy gray, with a large irregular whitish median band on the forewing and has a wingspread of about 14 mm.

Adults appear in June and early July and lay their eggs on the undersides of leaves. Young larvae feed for a short time on the leaves and then migrate to young twigs where they spin tiny, silken hibernacula in which to spend the winter. Feeding is resumed in the spring on opening buds and unfolding leaves, which are bound together with silk. Pupation occurs in June in silk-lined cocoons. There is one generation per year *(942)*. This species is most important as an orchard pest.

The **eastern pine shoot borer**, *Eucosma gloriola* Heinrich, is widely distributed in the Northeastern and Lake States and southern Canada. Its hosts are eastern white, jack, red, Scotch, Austrian, and Swiss mountain pines, and Douglas-fir. The adult is coppery red, with two shining, gray transverse bands on the forewings, and has a wingspread of about 15 mm.

Eggs apparently are laid on needle sheaths on new shoots or laterals during May or early June. Young larvae bore into the pith a few centimeters above the node of the new shoot and construct tunnels toward the tip several centimeters long. Infested shoots are eventually girdled from the inside *(333)*. The full-grown larva bores a hole to the outside through which it escapes and drops to the ground. There it spins a cocoon in the litter or just below the soil surface in which it pupates. Winter is spent in the pupal stage *(291)*.

The eastern pine shoot borer is a serious pest of young jack pines in the Lake States and Ontario and in eastern white, red, and Scotch pine plantations in New York and Pennsylvania. Infested terminals bend over or break off. Damaged laterals turn yellow, then red, and gradually die as the season advances. Infested trees become bushy after repeated attacks (fig. 54).

F-492898

Figure 54.—Damage to pine terminal by the eastern pine shoot borer, *Eucosma gloriola*.

Eucosma monitorana Heinrich, the **red pine cone borer**, attacks the cones of various pines in the Northeastern and Lake States and southern Canada. The adult is reddish brown with tan and silver markings on the forewings and has a wingspread of about 14 mm.

Young larvae enter the upper parts of second-year cones in June and bore down the cone axis. They feed on immature seeds until the supply is exhausted and sometimes sever the cone at the base. A single cone may contain up to 25 larvae. Final instars sometimes migrate to and enter relatively fresh cones. At first they bore around the cone for a short distance, then they tunnel toward and into the axis where they feed on surrounding seed. Mature larvae vacate the cones during July and drop to the ground to pupate, the stage in which the species overwinters. While on the ground, the larvae are vulnerable to prescribed burning *(855)*. There is one generation per year *(58)*.

Eucosma cocana Kearfott, the **shortleaf pine cone borer**, bores in cones mainly of shortleaf pine on the Eastern Seaboard *(360)*. The adult is rust colored with

shining white markings on the forewings and the wingspread is about 21 mm. Larvae feed from April to July, dropping to the ground for pupation and overwintering. There is one generation per year. *E. tocullionana* Heinrich, the **white pine cone borer**, has been recorded from Ontario and New Brunswick, Canada, and from Wisconsin, Massachusetts, New York, Connecticut, Pennsylvania, Virginia, North Carolina, and Tennessee. The larvae feed on the cones of various conifers, such as eastern white pine, spruce, balsam fir, and eastern hemlock *(996)*.

The **cottonwood twig borer**, *Gypsonoma haimbachiana* (Kearfott), has been recorded from Ontario, from the northern tier of States from New York to Michigan and south through the Midwestern States of Missouri, Oklahoma, Arkansas to Mississippi, Louisiana, and Texas. Its hosts are listed as various poplars. The adult is ash gray and has a wingspread of about 15 mm. The basal portion of the forewing is darker than the apical portion. Full-grown larvae are pale and about 15 mm long. The head is brownish yellow; the thoracic shield, brownish yellow edged with brown; and the anal shield, brown or grayish.

Winter is spent mostly as young larvae in silk-covered, shallow pits excavated in healed-over borer entrance holes, in the margins of corky bark ridges below leaf bases, or in depressions of leaf scars. Lesser numbers of late instars overwinter in hollowed-out terminal buds. When the younger larvae resume activity in the spring, they enter the tender, new shoots to feed and complete their development. When the older overwintering larvae resume feeding in the spring, they frequently kill the bud and up to 25 cm of the terminal. There appear to be four or five generations per year in the Mississippi Delta Region *(877)*.

This is one of the most destructive of the insects that damage young eastern cottonwood trees. Damaged trees are stunted, have crooked trunks, and produce too many limbs. This leads to a great reduction in the quality and quantity of merchantable pulpwood, saw logs, or veneer from these trees.

Proteoteras moffatiana Fernald feeds on terminal buds of maples. The resulting disruption in apical dominance causes forking and branching which seriously affects tree quality of sugar maple in the Lake States *(857)*. This insect occurs in the Northern United States and southern Canada from the Atlantic Coast to Wisconsin. The adult is bright green with irregular, brown forewing markings and has a wingspread of about 17 mm. There is one generation per year and adults are present in July and August. In late summer, larvae enter and mine terminal buds in which they pass the winter. In spring they mine additional buds before shoot elongation is completed.

Proteoteras aesculana Riley occurs throughout southern Canada and the Northern States, south to Tennessee. The adult is olive green with yellow, gray, and black markings, and has a wingspread of about 14 mm. The larvae bore in the seeds, leaf stalks, and terminal twigs of buckeye and maple and sometimes cause serious injury. Seedlings in nurseries have been heavily attacked. Adults emerge in July and August.

The **boxelder twig borer**, *P. willingana* (Kearfott), attacks boxelder and maple in many of the Northern and Midwestern States and southern Canada. The adult is white to brownish, marked with streaks, rings, and clusters of yellowish-tan to black scales; it has a wingspread of about 17 mm. The larva destroys dormant leaf buds in the fall and early spring. Later in the spring, it burrows in succulent twigs (fig. 55), causing the formation of spindle-shaped galls *(982)*. These galls become woody when they dry out. This usually prevents further terminal growth. Severe damage has been recorded in shelterbelt plantings in the Prairie Provinces of Canada.

F-500805

Figure 55.—Larva of the boxelder twig borer, *Proteoteras willingana*, in a boxelder stem.

The **spruce bud moth**, *Zeiraphera canadensis* Mutuura & Freeman, occurs throughout the range of spruce in the Northern United States and Canada *(984)*. In addition to spruce, it feeds on several other conifers, especially fir. The adult is light brown and has a wingspread of about 14 mm. The forewings have darker diagonal markings, and the outer margins are straight. Full-grown larvae are yellowish or grayish green and about 18 mm long.

Young larvae feed singly in opening buds in the spring or on tender terminal needles which they web together. Some pupae are found on the foliage of the trees, but the majority occur immediately below the ground surface. Winter is passed in the egg stage, and there is one generation per year. *Z. improbana* (Walker) occurs all the way across southern Canada and possibly in the northern tier of States. It appears to prefer larch and spruce, but several other conifers are also infested. The foregoing two *Zeiraphera* species were formerly thought to be European but now they are shown to be specifically distinct from their European counterparts *(900)*. *Z. unfortunana* Powell occurs commonly from coast to coast in southern Canada. Infestations also have been found in Maine. It apparently prefers white spruce.

The **maple trumpet skeletonizer**, *Epinotia aceriella* (Clemens), occurs from southern Canada to North Carolina. Its hosts are principally red and sugar maples, but it has also been collected on hawthorn and beech. The adult is white with dustings of gray or brown, and has a wingspread of about 15 mm. Each larva spins a long trumpetlike tube of silk and frass on the underside of a leaf, causing the leaf to

fold around it. It feeds from within this tube and skeletonizes the part of the leaf covered by the web, causing it to crumple. Damage is usually not very serious *(248)*. *E. solandriana* (L.) feeds as a leafroller on quaking aspen, paper birch, and various other hardwoods. It is sometimes abundant in the Northeast and Ontario.

Epinotia nanana (Treitschke), an introduced species first recorded in North America in Massachusetts in the early days of this century, now occurs from Maine to Ohio and Michigan and in Ontario, Quebec, and British Columbia. Its hosts are various species of spruce, especially white, Norway, and Colorado blue. The adult is dark, smoky brown and has a wingspread of about 11 mm. The forewing has a rather blunt apex, which is black and diffused below by a white dash. A blackish band crosses from the middle of the costa to before the anal angle. There are five distinct white spots on the costa of fresh specimens, and the wing is also flecked with whitish scales.

Adults are present during June in Canada and deposit their eggs on spruce needles. Newly hatched larvae attack the old needles, boring into them and hollowing them out completely. From the third instar on, they feed in about equal numbers on both old and new needles. A single larva may feed on several needles, which it ties together with silk. The winter is spent in the larval stage inside a mined needle. In the spring, the larva moves to a new needle and continues its feeding. Before reaching maturity, it may destroy several other needles, all of which are tied together in bunches appressed to the twig. Pupation occurs in silken cocoons in hollowed-out needles, in old staminate flowers, on the bark, or in litter on the ground. There is one generation per year *(278)*. Washing webs from the trees in the spring with a strong stream of water before the buds break has been suggested for control on ornamentals.

Ancylis platanana Clemens occurs commonly on sycamore wherever it grows in this country. The adult is whitish with pale, reddish forewings and has a wingspread of about 12 mm. Eggs are deposited along the midribs or larger veins on the undersurface of leaves during early spring. Young larvae feed on both sides of the midrib near the base, and spin fine, silken webs over the leaf surface. Older larvae feed beneath these webs and skeletonize the leaf. The winter is spent in the larval stage *(297)*. *Ancylis* spp. feed inside folded leaves of birch in the East, and populations occasionally become very heavy. Two common species are *A. discigerana* Walker and *A. logiana* L.

The **spruce seed moth**, *Cydia strobilella* (L.) (formerly *youngana* (Kearfott)), is widely distributed in the United States, Canada, and Eurasia. It attacks the cones of white, red, black, Colorado, Sitka, and Engelmann spruces. The larvae make tortuous mines near the cone axis, destroying both scales and seeds. White spruce cones are especially susceptible. The adult is smoky brown with four crossbars of shining silver and four shining costal spots on the forewings and has a wingspread of about 9 mm. Full-grown larvae are creamy white and about 10 mm long.

Winter is spent as a full-grown larva within a cone. Most of the larvae pupate in the spring; some may remain in diapause for 1 to 2 or more years *(1210)*. Female moths rarely fly; as a result, populations tend to build up on old cone-bearing trees.

The **hickory shuckworm**, *C. caryana* (Fitch), occurs in southern Canada and from the East Coast to Missouri and Texas in the United States. The larvae feed on hickory nuts and pecans. The adult is smoky black and has a wingspread of about 12 mm. Full-grown larvae are creamy white and about 9 mm long.

Adults appear in early spring (as early as mid-February in Florida) and lay their eggs on the nuts or foliage. Young larvae bore into and feed inside the nuts, thus

preventing future nut development. Winter is spent as a larva in the shucks of fallen nuts, and there are from one to four generations per year, depending on locality. Heavy infestations may seriously reduce hickory and pecan nut crops. Gathering and destroying infested nuts during the winter is helpful in control.

The **eastern pine seedworm**, *C. toreuta* (Grote), occurs over almost all the eastern half of the United States and southern Canada *(547)*. It attacks the second-year cones of various pines. The adult is gray brown with two prominent black-bordered silver bands across each forewing and has a wingspread of about 14 mm. The mature larva is creamy white and about 10 mm long *(360)*.

Adults emerge during late May and early June in the mid-South and during late June in Ontario and deposit their eggs in crevices on the surface of the cone. Young larvae bore into the upper part of second-year cones and feed from seed to seed as they spiral around the cone scales. Infestations appear to be heaviest on open-grown trees with branches to the ground or on trees in low-density stands *(693)*. Winter is spent as a full-grown larva in the woody axis of the cone, and pupation occurs in the spring. A braconid parasite, *Phanerotoma* sp., may destroy a high percentage of the full-grown larvae *(760)*.

The **slash pine seedworm**, *C. anaranjada* (Miller), occurs throughout the range of typical slash pine and South Florida slash pine in the South *(547)*. The adult has a wingspread of about 15 mm. The abdomen is pearl white and the forewings are yellowish orange to rusty orange, with four more or less equally spaced, mostly pearl-white crossbands. The species has been reared principally from mature cones of slash pine, occasionally from longleaf cones, and rarely from loblolly cones *(360)*.

Eggs are usually laid either singly or in small clusters on second-year cones. Young larvae bore into the cones and feed on the seed, moving from seed to seed, consuming their contents, and lining the tunnels between seeds with silk. A single larva consumes from five to seven seeds. Eventually, the full-grown larva bores into the woody cone axis where it spends the winter. Pupation occurs in the spring, and the adults emerge during April and May. There is one generation per year. According to estimates, this species destroys from 2 to 10 percent of the seed in open-grown slash pine stands in northeast Florida each year *(836)*.

The **longleaf pine seedworm**, *C. ingens* (Heinrich), has been recorded from South Carolina, Georgia, Florida, Alabama, and Mississippi and probably occurs throughout the range of its favored host, longleaf pine. It also infests slash and loblolly pines to a minor extent and may occur occasionally on other southern pines *(360)*. The adult is grayish brown and has a wingspread of about 18 mm. Eggs are laid in rows of two to nine eggs each on scale apophyses of 1-year-old cones. Young larvae bore downward through the scales and enter seeds through the micropyle. Larvae feed during the first two instars, each in a seed, vacating it and tunneling through the cone in search of another seed. Before it reaches maturity the larva may consume two to five additional seeds. A full-grown larva bores into the rachis and usually tunnels toward the base for a distance of 2.5 to 5 cm. Winter is spent in the larval stage in this tunnel. Pupation occurs in the spring, usually between mid-March and mid-May, and the adult appears about 1 to 2 weeks later. There is one generation per year, except for occasional individuals that enter diapause *(255)*. This species causes an estimated loss of 21 percent of longleaf pine seed in the Gulf States region.

The **filbertworm**, *Melissopus latiferreanus* (Walsingham), occurs throughout most of the United States and in southern Canada. The larvae feed in hazelnuts,

filberts, acorns, beechnuts, chestnuts, and oak galls. The adult is reddish brown and has a wingspread of 11 to 20 mm. High percentages of acorn crops may be destroyed during poor seed years.

Endopiza liriodendrana (Kearfott) has been recorded feeding on yellow-poplar in New Jersey and on magnolia in Florida. The adult is brownish or blackish, and there is a tuft or mass of erect, dark-colored scales at the rear of the thorax. Eggs are laid on the leaves from May to September. Young larvae bore into the midvein near the petiole and feed in mines during the first instar. Older larvae feed under webs spun on the lower surface of the leaves or between two leaves webbed tightly together. Pupation occurs under the web *(979)*. *E. palliolana* (McDunnough) attacks terminals of eastern larch *(892)*.

The **locust twig borer**, *Ecdytolopha insiticiana* Zeller, attacks black locust throughout the Eastern United States and in parts of southern Canada. It also occurs in Colorado, Arizona, and California. The adult has a wingspread of about 22 mm. The forewings are dark, ashy brown with large, dull, pinkish-white patches on their outer parts with several small, blackish spots near the middle of each of the patches. Full-grown larvae are reddish to straw yellow with a darker dorsal line, and are about 16 mm long.

Adults are present from early May to the end of June and again from July to October. The larvae are twig or stem borers, and cause the formation of elongate galls up to 7.5 cm long. Winter is passed as a mature larva in a cocoon among the leaves on the ground. In heavily infested areas, seedling mortality may be high. A high percentage of the twigs on larger trees also may be damaged.

Other olethreutine moths likely to be encountered in eastern forests and their hosts are as follows: *Hedya chionosema* (Zeller)—hawthorn, occasionally red oak and mountain-ash; the **raspberry leafroller**, *Olethreutes permundana* (Clemens)—hickory; *O. quadrifidum* Zeller—cherry; *Pseudosciaphila duplex* (Walsingham) and *Pseudexentera oregonana* (Walsingham)—poplar; *Epinotia stroemiana* (F.)—gray birch; *E. lindana* (Fernald)—alternate-leaved and flowering dogwood; *Griselda radicana* Heinrich—various conifers, principally white spruce and balsam fir; the **pecan bud moth**, *Gretchena bolliana* (Slingerland), and *G. concitatricana* (Heinrich)—black walnut.

Subfamily Tortricinae

Members of this subfamily eat the foliage of a wide variety of coniferous and deciduous trees of all sizes and ages. Many species are important pests, some extremely so. The larvae either fold or roll individual leaves or parts of leaves or tie several leaves or shoots together forming enclosures in which to rest and feed or from which they move out to feed. The adults are usually small and have wide, oblong, fringed wings that appear bell-shaped while at rest. The wingspread is about 25 mm. The larvae are usually some shade of green, seldom more than 25 mm long, and they pupate in flimsy silken cocoons. Just before the pupa transforms to the adult, it works its way partly out of its cocoon. Information about many species has been summarized *(446, 794)*.

Adoxophyes furcatana (Walker), a leafroller on sycamore, occurs from New England to Pennsylvania and the Mississippi River Valley. The adult is straw yellow and has a wingspread of 20 mm. The forewings are marked with five golden-brown lines and two irregular light-brown bands. The hindwings and their fringes are shiny white. Full-grown larvae are light green, taper toward each end, and are about 18 mm long.

Amorbia humerosana Clemens occurs from coast to coast in southern Canada and in the Northeastern States south to Pennsylvania. Its hosts include a wide variety of tree species, both coniferous and deciduous. Adults are light gray and have wingspreads of about 25 mm. Larvae are light green except for light-brown heads.

Sparganothis acerivorana (MacKay) occurs in southern Canada and the Lake States. In Canada it feeds on several hardwoods, mostly sugar and red maples, and also on young Scotch and red pines. In the Lake States, it usually feeds on sugar maple. The adult is reddish yellow with reddish-brown spots and has a wingspread of about 25 mm. Full-grown larvae are yellowish green and about 21 mm long. Winter is apparently spent in the egg stage, and hatching occurs during May of the following spring. Each larva rolls a leaf in which to rest and from which it moves out to feed. Pupation occurs inside the roll.

Defoliation by this species was an important factor leading to the development of maple blight, a condition responsible for the deterioration and death of large numbers of sugar maple trees in Wisconsin *(483)*.

Sparganothis pettitana (Robinson) occurs in southeastern Canada and south and west to Florida and the Mississippi River Valley. The larvae are solitary leafrollers on various hardwoods, especially basswood and maples. The adult is lemon yellow and has a wingspread of about 22 mm. The forewings are sometimes marked with two oblique lines of light-brown scales, and the hindwings are white. Full-grown larvae are dull, yellowish green, with reddish-brown heads and brown to blackish cervical shields.

Sparganothis sulfureana (Clemens) has been observed feeding in the tips and shoots of small red pines in Canada and in the terminals of loblolly pine seedlings in Georgia. Willow, honeylocust, apple, and cherry are also attacked. *S. reticulatana* (Clemens) occurs over about the same range as *S. sulfureana*. It feeds on white ash, maple, bigtooth aspen, and paper birch. *S. diluticostana* (Walsingham) occurs commonly on oak in New Jersey and Maine. It has also been recorded feeding on white ash and paper birch in southern Canada. *S. tristriata* (Kearfott) occurs fairly commonly on jack pine in southern Ontario. It probably occurs in the Lake States also.

The genus *Pandemis* contains several species that attack a wide variety of hardwoods in eastern North America. *P. lamprosana* (Robinson) feeds on beech, paper birch, red and sugar maples, oak, elm, basswood, ironwood, and sassafras from Maine to New Jersey and in southern Ontario and Quebec. The **threelined leafroller**, *P. limitata* (Robinson), occurs from coast to coast in Canada. It has also been recorded from Maine, Pennsylvania, Georgia, Illinois, and Arkansas. Its hosts include paper birch, willow, oak, basswood, elm, boxelder, alder, and cherry.

Archips rosanus (L.), an introduced species, occurs in southeastern Canada, British Columbia, and from New England to the Lake States. The larvae are general feeders on a number of deciduous species. Privet appears to be especially attractive. Adults are dull light-brown to olive-brown and have wingspreads of about 20 mm. Full-grown larvae are dull green and about 18 mm long. The larvae tie together two or more leaves at the tips of twigs or branches and feed on them during May and June.

The **uglynest caterpillar**, *A. cerasivoranus* (Fitch), occurs from coast to coast in the Northern States and southern Canada. Its preferred hosts are common chokecherry and black cherry, but it may also be found on a wide variety of other hardwoods. The adult is dull orange and has a wingspread of about 21 mm. The

forewing is irregularly speckled with dark reddish-brown and has three patches of the same color. The hindwing is bright orange. Full-grown larvae are yellowish or greenish yellow except for black heads and cervical shields, and are about 20 mm long.

Winter is spent in the egg stage. Hatching begins in May, and larvae are present until September, depending on location. They live together in dense nests they construct by webbing twigs and leaves together (fig. 56). In heavily infested areas, these nests are often numerous. Some may be large enough to entirely enclose small trees.

The uglynest caterpillar is usually of little or no economic importance because the trees attacked are usually of low value. However, the presence of its webs on roadside vegetation may be objectionable because of their unsightliness. Cutting and removing nests provides adequate control in most situations.

The **oak webworm**, *A. fervidanus* (Clemens), occurs throughout the oak regions of the Northeastern and Lake States and in various parts of southern Canada. Its favored hosts appear to be scrub and bur oaks, but it also feeds on the seedlings and sprouts of several other oaks. The adult is brownish and has a wingspread of about 21 mm. The forewing is yellowish brown with dark patches. The hindwing is uniformly smoky except for a light-colored fringe marked with a fine, basal line. Full-grown larvae are grayish green and about 20 mm long. Larvae live together in webs, some of which may be 8 cm wide and up to 0.5 m long (fig. 57). Occasionally, they are large enough to enclose all of the leaves at the top of a tree. Winter is spent in the egg stage. Larvae appear in midsummer, and pupation occurs within the nest. The species is of little economic importance.

F-519520

Figure 56.—Nest of the uglynest caterpillar, *Archips cerasivoranus*, on wild cherry.

The **fruittree leafroller**, *A. argyrospilus* (Walker), occurs throughout the United States and from coast to coast in southern Canada. Its hosts include many fruit trees and many forest and shade trees such as ash, hickory, elm, oak, maple, walnut, poplar, birch, basswood, and buckeye. The adult is pale yellow to orange-red and has a wingspread of about 21 mm. The forewings are mottled with golden scales, their tips triangular. The hindwings are fuscous and have dirty-white fringes. Full-grown larvae are light green and about 22 mm long.

Adults are present from June to August, depending on location. Eggs are deposited in small, round or convex masses containing about 100 to 150 eggs each, usually on twigs or small branches. Winter is spent in the egg stage, and hatching occurs in early spring. Young larvae feed on opening buds, blossoms, young fruit, and unfolding leaves which they web together with silk. Later, several leaves may be webbed together, forming a nest in which the larvae live and from which they move out to feed. Pupation occurs in flimsy cocoons spun inside the nest or on the branches or trunk of the tree. A number of outbreaks of this species, some of which covered tens of thousands of hectares, have occurred in oak stands in Eastern and Lake States.

Archips semiferanus (Walker) defoliated oaks on more than 400,000 hectares in midcontinent areas *(378, 1330)*. Northern red, scarlet, and northern pin oaks of all ages are affected. The adult is light olive brown with a diagonal rusty band on the forewing; the wingspread is about 22 mm. Mature larvae are greenish yellow and about 21 mm long. Masses of 15 to 125 eggs covered with tan scales from the female's abdomen are deposited on the bark of tree crowns during July and early August. Hatching occurs the following spring, in mid-May, about the time of

Courtesy Conn. Agric. Exp. Stn.

Figure 57.—Nest of larvae of the oak webworm, *Archips fervidanus*.

budbreak. At first, larvae feed within the protective folds of young leaf clusters and later roll or fold one or more entire leaves or leaf parts. Pupation takes place in leaf rolls in June and adults appear in July.

Many other species of *Archips* are also encountered in eastern forests *(446)*. A few of these and some of their hosts are as follows: *A. infumatanus* (Zeller)—hickory and pecan, *A. negundanus* (Dyar)—boxelder, *A. rileyanus* (Grote)—hickory and walnut, *A. georgianus* (Walker)—oak, *A. griseus* (Robinson)—oak and hickory, *A. magnolianus* (Fernald)—cucumbertree, and *A. purpuranus* (Clemens)—basswood, paper birch, quaking aspen, willow, and black cherry.

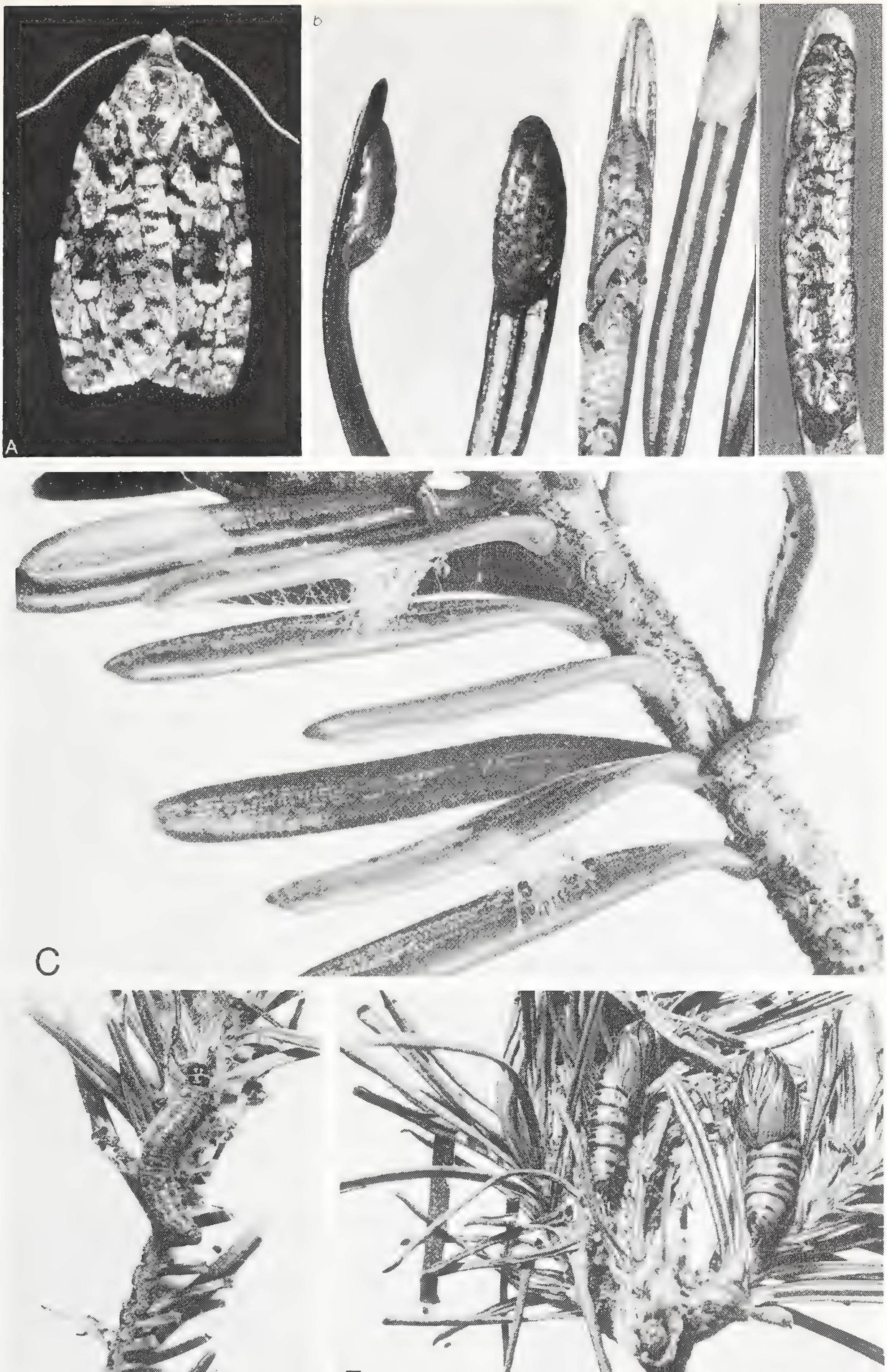
The **spruce budworm**, *Choristoneura fumiferana* (Clemens) (fig. 58), occurs in North America from Virginia to Labrador and westward to the MacKenzie River Valley, Yukon Territory *(1150)*. At one time, it had been considered present throughout the ranges of spruce and fir in North America. Forms occurring in western Canada and the Western United States are now considered different species *(448, 997)*; however, the question of speciation does not appear to be settled *(997, 1165)*. Balsam fir is the preferred host of the spruce budworm. To a lesser degree, it also feeds on white, red, and black spruces, and on larches, pines, and eastern hemlock *(698)*.

Spruce budworm adults are mostly gray, sometimes ochreous gray. The male has a wingspread of about 24 mm; the female, about 26 mm. Full-grown larvae are about 20 to 23 mm long. The head is usually almost entirely dark brown, the prothoracic shield is brownish yellow with some diffusion of brown pigment or is entirely dark brown, and the anal shield is brownish yellow. Pupae are light to reddish brown except for darker bands and spots.

Spruce budworm adults are active from late June to early August, depending on location, and the females deposit their eggs in elongate masses of 2 to 60 eggs each, the eggs overlapping like shingles on a roof. A large proportion of the masses are usually found on needles near the periphery of the crown. The eggs hatch in about 10 days under normal conditions. After a period of 1 to 2 days, during which larvae are dispersed by wind throughout the tree and stand, the larvae spin hibernacula in suitable sites and molt to the second instar. While the majority of hibernacula are found on the branches of host trees, some are also found in mined buds, in flower scars, under bark scales, or under lichens. Many larvae become dislodged while searching for overwintering sites and drop down on silken threads. At this time, they may be blown considerable distances by the wind, often into uninfested stands.

In the spring, after several days of warm weather but before balsam fir buds expand, the overwintering larvae emerge and start to feed. The new buds of staminate flowers are attacked first if present; otherwise, the larvae bore into old needles. After a short period of feeding here, the larvae move to the ends of branches and bore into expanding, vegetative buds. Later, they feed on the new foliage of developing shoots. When about half grown, they begin tying the tips of two or more twigs together with silk, forming a small nest. During this period, old needles are avoided until all of the new ones are eaten or cut through. Feeding is usually completed during late June or early July. Pupation usually takes place within the last-formed nest but may occur at twig axils. Adults appear in about 10 days and are subject to considerable dispersal by the wind. The female does not fly until she has deposited one or two egg masses. Wind dispersal may be the most important factor influencing population trends in any given area *(503, 882)*.

In light or moderate infestations, spruce budworm injury is restricted to the partial loss of new foliage, especially in the upper portion of the crown. Damaged



A,B,C,E, courtesy Can. For. Serv., Can. Dep. Environ., Sault Ste. Marie, Ont.
D, courtesy S. J. Krieg, Emporium, Pa.

Figure 58.—Spruce budworm, *Choristoneura fumiferana*: A, moth; B, egg masses: left—unhatched; center—shows hatched and unhatched as well as hatching, with completely hatched mass to the right; right—egg mass parasitized by *Trichogramma minutum*; C, instar II; D, final instar; E, pupae.

needles on webbed branch tips turn reddish brown by midsummer. In heavy, persistent infestations, all of the new foliage may be consumed (fig. 59) for several successive years, and opening vegetative buds and developing shoots may be killed in their formative stages. Top-kill usually occurs after about 3 years of severe infestation, and tree mortality, after about 5 years. In sustained outbreaks, nearly complete mortality of the merchantable volume of balsam fir may occur by the 8th year *(89, 799)*. During widespread outbreaks, the magnitude of these losses is great.

F-492901

Figure 59.—Balsam fir defoliated by the spruce budworm, *Choristoneura fumiferana*.

Much has been learned about the factors or conditions conducive to the development and decline of spruce budworm outbreaks. For example, it was determined many years ago *(1182)* that outbreaks generally begin in extensive and continuous areas of mature and overmature balsam fir. Later, it was learned that even when these conditions prevail, at least three or four summers of clear, dry weather are necessary for populations to explode *(502, 985, 1271)*. Much has also been learned

about factors tending to hold populations in check during intervals between outbreaks or which assist in bringing them under control once they are underway *(127, 882)*.

The spruce budworm has many natural enemies, including parasites and predators, birds, mites, spiders, and several pathogenic organisms. Their effectiveness in control is always important, but it is greatest only after another agent, such as weather or starvation, has reduced the budworm population considerably *(848)*. A number of authors have evaluated the control effectiveness of natural enemies in specific outbreaks *(124, 126, 329, 330, 636, 787)*.

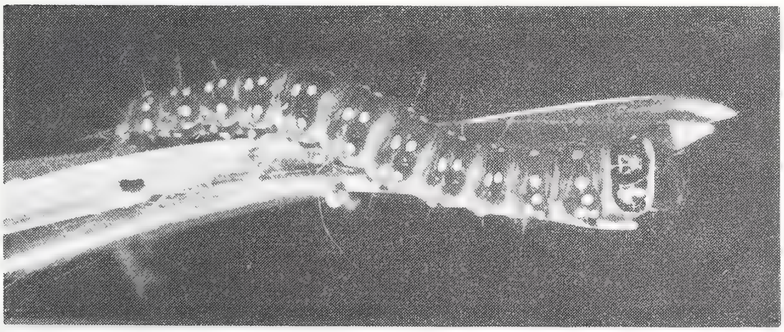
Other important natural control factors affecting the spruce budworm are: (1) the loss of young larvae through competition for new foliage in heavy infestations; (2) loss of young larvae as a result of cooler than normal temperatures and late frosts in the spring; (3) loss of large larvae through starvation following complete defoliation; and (4) loss of adults through dispersal.

A number of management practices have been suggested for reducing the chances of spruce budworm outbreaks. These include the utilization of balsam fir *(125, 1182)*; the regulation of age classes to prevent the occurrence of large areas of overmature fir *(125, 498)*, and the favoring of less susceptible species, such as red spruce. Discussions that favor forest management oversimplify the special relationships between the budworm and balsam fir *(66)*.

The removal of overstory mature balsam fir was suggested for preventing outbreaks *(806, 1277)*; management plans and risk-rating systems for selective cutting were presented *(807, 808, 1278)*; and risk-rating systems for the Lake States were devised *(69, 70, 78, 495)*. Publications on the budworm and forest management in the Maritime Provinces of Canada are available *(46, 195)*.

For further information on the spruce budworm, the reader is referred to reviews of the literature *(66, 638, 797)*.

The **jack pine budworm**, *C. pinus pinus* Freeman, is known to occur in Nova Scotia, Ontario, Manitoba, and from Michigan to Minnesota. Its hosts include various species of pine, especially jack and red. The adult has a wingspread of about 22 mm. The head, thorax, and forewings are ochreous-tawny; the forewings, distinctly maculate; and the hindwings smoky with dark basal lines through their white fringes. The full-grown larva has a shiny light-brown to black head, a dark-brown "collar" separated from the head by a narrow white band, a reddish-brown body with yellowish sides, and two rows of white dots along the back; it is about 21 mm long (fig. 60). Pupae are pale green when just formed; later, they become dark reddish-brown, and they are about 12 mm long.



Courtesy Can. For. Serv., Can. Dep. Environ., Sault Ste. Marie, Ont.

Figure 60.—Larva of the jack pine budworm, *Choristoneura pinus pinus*, feeding on needles of jack pine.

Jack pine budworm adults are present from early July to early August and lay their eggs in clusters of about 40 in two or three rows on the flat side of a pine needle. Hatching occurs in about 10 days. A few days later, the young larvae, without feeding, spin hibernacula under bark scales on the trunk or larger limbs, or between needles. Then they molt to the second instar, the stage in which they remain throughout the rest of the summer, fall, and winter. In the spring, about the time the staminate flowers are shedding their pollen, they emerge and begin feeding on the pollen. Some usually remain in the flower clusters throughout the entire feeding period, but the majority migrate to new foliage on which they feed, once it is well developed. The needles are not consumed entirely, but are usually clipped off at the base and webbed together. Pupation occurs among the needles or between webbed shoots.

The jack pine budworm usually does not cause heavy mortality of merchantable jack pine, but it may cause top-kill and "stag-headedness." During outbreaks, however, heavy losses in pole-size trees, saplings, and reproduction may result. In heavily infested stands, young understory red and eastern white pines also are often severely defoliated and killed. Fortunately, outbreaks usually last only 2 to 4 years.

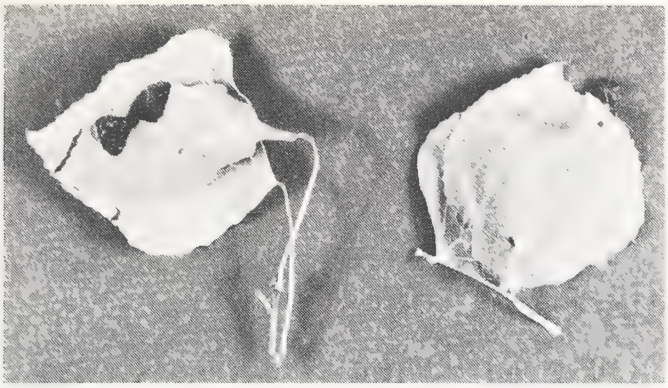
Cutting practices designed to remove the jack pines that most commonly produce staminate flowers are helpful in preventing outbreaks *(580)*. These trees are usually coarsely branched and large-crowned, or suppressed and slow growing. Growing hard pines in fully stocked stands or in groups, eliminating large-crowned "wolf" trees, utilizing trees before they become mature, and encouraging species suited to the site are also recommended practices *(674)*. Parasites and a polyhedral virus disease aid in the control of infestations following periods of heavy defoliation. Rapid declines in populations have also been attributed to decreases in staminate flower production.

A subspecies, *C. pinus maritima* Freeman, has been found feeding on Virginia and pitch pines in Pennsylvania, Massachusetts, New Jersey, and Kentucky. Adults are larger and redder than those of the jack pine budworm *(448, 997)*.

The **large aspen tortrix**, *C. conflictana* (Walker), occurs throughout much of the range of quaking aspen in Canada and the United States *(1288)*. Several other hardwoods also serve as hosts such as balsam poplar, bigtooth aspen, paper birch, willow, and alder. The adult is dull, light gray and has a wingspread of about 28 mm. Full-grown larvae are usually dark green, sometimes almost black, and are about 16 mm long. The prothoracic shield is reddish brown to black; the thoracic legs, black.

In Canada, eggs are laid in flat clusters usually on the upper surfaces of leaves in June or July. The first instars feed gregariously on leaf surfaces during July, spinning much silk and webbing the surfaces together (fig. 61). Later they move to the trunk in search of hibernation sites in rough bark or under moss. Here they molt and spend the winter as second instars. The following spring, they climb the trees and mine the swelling buds. Later, they roll leaves and feed within the enclosures. Pupation occurs within the rolls, and adults begin to emerge in June *(1001)*. Many outbreaks have occurred in aspen stands in Canada. Serious defoliation has also been recorded in New England, New York, and Michigan.

The **obliquebanded leafroller**, *C. rosaceana* (Harris), occurs in southern Canada and throughout most of the United States. It is recorded as a general feeder on the foliage of deciduous trees and shrubs. In Canada, it occurs most frequently on quaking aspen, paper birch, and willow but has also been observed feeding on Scotch pine. In New York, it has seriously damaged coniferous seedlings in



F-506744

Figure 61.—Pupae of the large aspen tortrix, *Choristoneura conflictana*, in webbed leaves.

nurseries *(1088)*. Seedlings most seriously affected were those of eastern white, Scotch, and red pines. The infestation is believed to have resulted from an invasion of the nursery by larvae developing on weeds or other vegetation surrounding the nursery. The adult is reddish brown and has a wingspread of about 25 mm. The forewings are marked with three dark-brown, oblique bands. Full-grown larvae are greenish and about 9 mm long.

Winter is spent as young larvae in tightly woven cases under bud scales or loose bark, or between leaves. The following spring the larvae feed first on the surface of unfolding leaves. Later, each larva ties two or more leaves together with silk and feeds from within the case. Adults may appear as early as June, and there may be two generations per year, depending on location.

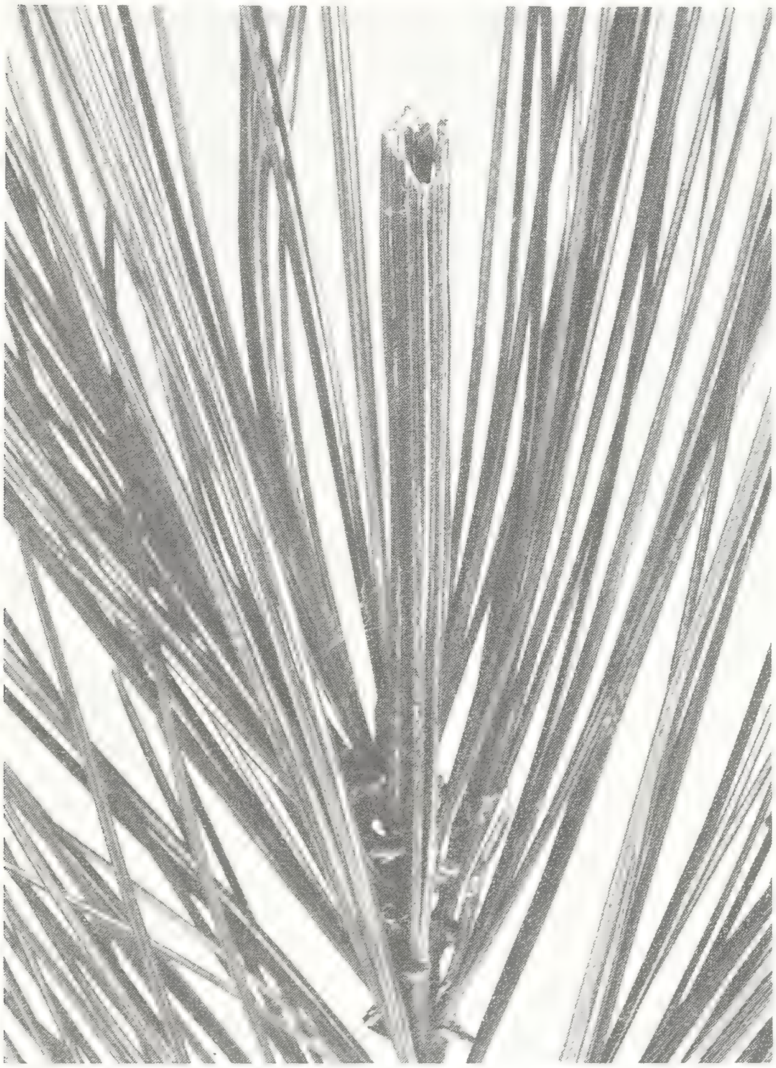
Choristoneura fractivittana (Clemens) feeds on sugar maple, beech, paper birch, red maple, elm, and red oak in southern Canada and from Massachusetts to Wisconsin and Colorado. It is sometimes mistaken for *C. rosaceana*.

Cudonigera houstonana (Grote) attacks various species of *Juniperus*, especially eastern redcedar, and is a pest in windbreak and ornamental plantings in western Kansas *(554)*.

The **redbanded leafroller**, *Argyrotaenia velutinana* (Walker), occurs in southern Canada, mostly in the southeastern part, and throughout the Eastern United States, westward to Iowa, Missouri, and Texas. In Canada and Maine it occurs commonly on various conifers, especially white, red, and black spruces, balsam fir, and larch. In the United States, it occurs on a wide variety of deciduous trees. Damage is often serious in apple orchards. The adult has a wingspread of about 14 mm. The forewing is marked with a band that widens as it runs from the middle of the costa to the outer third of the inner margin. Full-grown larvae are pale green and about 16 mm long. Winter is spent in the pupal stage among leaves and debris on the ground, and there may be three or four generations per year. A granulosis virus disease that tends to retard larval development has been reported in Virginia. Eggs are sometimes heavily parasitized by *Trichogramma minutum* Riley.

The **pine tube moth**, *A. pinatubana* (Kearfott), feeds on various pines, mostly eastern white pine, in southern Canada, the Northeastern States, Florida, and Louisiana. The adult is small, slender, and grayish; it has a wingspread of about 14 mm. The forewings have broad, orange to reddish-ochreous patches and are crossed by two whitish, oblique lines; the hindwings are smoky; and the abdomen is gray, blackish, or mouse colored with ochreous, apical tufts. Full-grown larvae are 12 mm long.

The larva lives within the tube it constructs by drawing from 5 to 20 needles together and fastening them with silk. It feeds on the tips of these needles (fig. 62). Winter is spent in the pupal stage within the tube. There may be two generations per year. Heavily infested pines often have a ragged appearance. This may be objectionable where valuable ornamentals are involved.



Courtesy Conn. Agric. Exp. Stn.

Figure 62.—Larval tube and larval feeding damage by the pine tube moth, *Argyrotaenia pinatubana*.

The **hickory leafroller**, *A. juglandana* (Fernald), occurs in southern Canada and throughout the Eastern States. Its principal host is hickory, but it will feed on plum and viburnum. The adult is dark brown and has a wingspread of about 21 mm. The front wings are marked by two parallel, oblique, blackish bands. Full-grown larvae are pale to translucent, with pale green heads tinged with brown; larvae are about 20 mm long. They feed from within longitudinally rolled leaves and pupate beneath the bark on the trunk of the tree.

Argyrotaenia quercifoliana (Fitch) occurs in southern Canada and south to Florida and Texas. The larvae feed on the foliage of red, black, white, scrub, and pin oaks. The adult is cream yellow marked with light-brown dots and has a wingspread of about 20 mm. The forewings are marked with two oblique brown bands, and the hindwings are white. Full-grown larvae are light green except for amber-yellow heads and are about 20 mm long. This species sometimes causes serious defoliation locally.

Several other species of *Argyrotaenia* are recorded as feeding on eastern trees *(446)*; *A. occultana* Freeman—on spruce and occasionally balsam fir and larch in Canada and New York; the **graybanded leafroller**, *A. mariana* (Fernald)—on paper birch, willow, chokecherry, elm, pear, *Vaccinium*, and possibly oak from eastern Canada to Florida; *A. quadrifasciana* (Fernald)—on hawthorn, serviceberry, plum, and pear in southeastern Canada and from Maine to Missouri; and *A. alisellana* (Robinson)—on oak from southern Canada to Florida.

The **oak leaftier**, *Croesia semipurpurana* (Kearfott), feeds on various oaks from southeastern Canada and Massachusetts to Minnesota and Texas. Adults have wingspreads of about 12 mm. The forewings vary in color from almost solid yellow to yellow with dark-brown markings. The full-grown larva is dirty white to light green except for a pale head and brown to black thoracic legs, and is about 12 mm long.

Eggs are laid individually on the bark of second-year wood of branches in late June and early July and hatch in April of the following year. Newly hatched larvae enter unopened buds and feed on the young leaves. Older ones fold together sections of leaves and feed inside the folds. When they reach maturity in May, they spin down to the ground and pupate in the litter. Adults appear 1 to 2 weeks later.

Serious outbreaks have occurred in the Northeastern and Middle Atlantic States *(210)*. During 1964 and 1965, approximately one-quarter million hectares of red oaks were severely defoliated in Pennsylvania alone, resulting in considerable tree mortality.

The **eastern blackheaded budworm**, *Acleris variana* (Fernald), occurs from Cape Breton Island and the northeastern corner of the United States across the coniferous forest region of Canada to Saskatchewan and eastern Alberta. (The western blackheaded budworm occurring farther west is now considered to be a different species, *A. gloverana* (Walsingham) *(995)*.) Balsam fir is its preferred host, but during epidemics, white and sometimes red and black spruces and hemlock may also be defoliated *(770)*. The adult is predominantly mottled gray with various brown, white, or gray ragged bands across the wings. Some individuals have a white, yellow, or orange stripe down each wing. The wingspread is about 19 mm. Full-grown larvae are bright green and about 14 mm long.

Adults appear during August and September and deposit their eggs singly on the undersides of needles, mostly on the upper branches. The winter is spent in the egg stage. Hatching occurs in the spring, and the young larvae burrow into the expanding buds. As the new needles grow, the larvae web together a few of them and feed within. Once the new needles are devoured, the larvae feed on the old ones. Pupation occurs within webbed masses of partially eaten and damaged needles.

Extensive outbreaks tend to occur at intervals of 10 to 15 years in stands where maturing balsam fir is dominant, but they usually subside before many trees are killed.

Acleris chalybeana (Fernald) has been recorded from Ontario, Quebec, Wisconsin, Maine, New York, and Pennsylvania. The larvae feed on the foliage of sugar, red, and mountain maples, yellow birch, beech, and eastern hophornbeam. The adult is grayish and has a wingspread of about 21 mm. Full-grown larvae are light green and about 19 mm long. In Wisconsin, apparently they winter as first or second instars in hibernacula on the twigs. During June, the majority of them were found in rolled leaves previously occupied by larvae of another tortricid, *Sparganothis acerivorana*; the remainder rolled their own leaves. Pupation occurs inside the roll. Damage by this species appears to have been one of the factors contributing

to the development of maple blight, a condition leading to the deterioration and death of sugar maples and saplings *(483)*. *A. logiana* (L.) skeletonizes the leaves of paper and river birches. Larvae are dull green, with the head, cervical shield, and front legs black; they have black warts on the prothorax. They usually feed singly inside folded leaves. Sometimes they are found between two leaves folded together. *A. tripunctana* (Hübner) feeds on paper birch.

Aphelia alleniana (Fernald) normally feeds on weeds and clovers, but may also attack and injure small seedlings in coniferous plantations. Seedling losses have been severe in the Lake States and southern Canada. The larvae tie the shoots of the seedlings together and feed from within the sheath on the stems and new needles during May and June. Injured seedlings become twisted and deformed. Winter is spent in the larval stage, and there is one generation per year.

Xenotemna pallorana (Robinson) also normally feeds on weeds and clover, but it also occasionally damages seedlings in young coniferous plantations in the Lake States and southern Canada. It is widely distributed in the Eastern United States, occurring from New England to the Lake States, Missouri, and Texas. The larvae pull the young shoots of seedlings together, fastening them with loose silk. Then, they feed on the young needles and tunnel into the shoot. Heavy damage to young eastern white, red, jack, and Scotch pines has been recorded during May and June in Michigan. There are two generations per year in Ontario. Winter is spent as larvae in hibernacula spun within folded leaves *(818)*.

Family Cochylidae
Cochylids

The moths of this family resemble those of the subfamilies Olethreutinae and Tortricinae. Only one eastern species is worthy of mention.

Aethes rutilana (Hübner) is an introduced species first recorded in this country in 1878. Its present distribution seems to be limited to southern Canada and from New England to New Jersey and Indiana. Its host plants are various junipers, especially common juniper on which it is often abundant. The adult is yellowish and has a wingspread of about 10 mm. There are red markings on the head, thorax, and forewings, those on the wings occurring as four broad crossbands. The larvae spin webs on the foliage, tying the needles together and forming tubes in which they live and feed. Pupation takes place on the tree in the webbing. The foliage of heavily infested trees may turn brown.

Family Hesperiidae
Skippers

Members of this family are commonly known as skippers because of the way the adults flit or dart from place to place. They are distinguished by the head that is nearly as wide or wider than the thorax, and the antennal club that usually ends in a recurved hooklike apiculus. The larvae usually have large heads and strongly constricted necks. They are also usually solitary, each one concealing itself under part of a leaf that it cuts and folds over.

The **silverspotted skipper**, *Epargyreus clarus* (Cramer), one of the largest species in the family, is widely distributed throughout the United States and southern Canada, and the larvae feed on black locust and wisteria. Adults are brown except for yellow and white triangular spots on the forewings. The forewings are elongate, and the hindwings have rounded tips. Full-grown larvae are nearly 50 mm long. The body is leaf-green, the head dull red except for two yellow spots on the lower part of the face, the neck and sides of the first thoracic segment are red, and the cervical shield is black. The body is also marked with dark rings.

The larvae feed from within nests made by tying several leaves together with silk. Sometimes they cause heavy defoliation locally. Pupation takes place in loose cocoons spun among the leaves, usually on the ground. In the South there are two generations per year, farther north there may be only one generation or one and a partial second.

Family Papilionidae
Swallowtail Butterflies

Swallowtail butterflies are of considerable interest to many people because of their large size and striking appearance; otherwise, they are of minor importance. The adults are distinguished by the wavy margins and taillike prolongations of the hindwings; the larvae, by the protrusile, bright-colored, forked processes rising from the first thoracic segment. These processes also emit a disagreeable odor when the caterpillar is disturbed.

The **tiger swallowtail**, *Papilio glaucus* L., commonly occurs in eastern North America. The caterpillars feed on various deciduous trees such as ash, birch, basswood, cherry, and poplar. Full-grown larvae are dark green and about 37 mm long. The third thoracic segment is enlarged and marked on each side by a large yellow spot. This spot is edged with black and encloses a small purple spot that is also edged with black. The distal part of the first abdominal segment bears a transverse, yellowish ridge, edged posteriorly with black. The caterpillar spins a silken mat upon the surface of the leaf which usually causes the leaf to fold lengthwise. Resting caterpillars are found inside this fold. Transformation to the chrysalis usually takes place on some object above the ground.

The **spicebush swallowtail**, *P. troilus* L., occurs throughout the eastern part of the United States and its principal food plants are spicebush and sassafras. Full-grown larvae are about 37 mm long. The body is widest at the third thoracic segment. The head and venter are pink, the dorsum pea-green, the sides yellowish, and there is a transverse black line on the prothorax. The third thoracic and first abdominal segment each bears two orange spots. Those on the thorax have black centers. Six small spots are on second and seventh abdominal segments and four on the eighth. *P. cresphontes* Cramer feeds on prickly-ash in the Northern States and on citrus in the South.

Graphium marcellus (Cramer), the **zebra swallowtail**, feeds on pawpaw.

Family Nymphalidae
Brushfooted Butterflies

This family contains some of our most common butterflies. The adults are medium to large and are distinguished by having the forelegs much reduced and without claws. Only the middle and hind pairs are used for walking. The head of the caterpillar is usually bilobed, the tips of the lobes often supporting branched spines, and the body is spiny or bears fleshy, hair-covered warts. The chrysalids are naked and are usually suspended by the cremaster.

Polygonia interrogationis (F.), the **question-mark**, feeds on elm, basswood, and hackberry in eastern America, especially on sprout growth along roadsides. Full-grown caterpillars (fig. 63) are brownish with yellow mottlings and are about 37 mm long. Each body segment bears a transverse row of light-colored branched spines. There are two generations per year. *P. comma* (Harris), the **comma**, occurs on elm, nettle, and hops from Canada to the Carolinas and Texas. Full-grown caterpillars are yellowish white, and each body segment bears a transverse row of branched spines.

F-519524

Figure 63.—Larvae and chrysalis of the butterfly, *Polygonia interrogationis*, the question-mark.

Nymphalis vau-album (Denis & Schiffermüller), the **Compton tortoiseshell**, feeds principally on gray and paper birches, but also on poplar and willow in Canada and south to Pennsylvania in the Eastern States. Caterpillars have black heads, the body is reddish to blackish on the dorsum with dots of light green, and each segment bears a transverse row of branched spines.

The **mourningcloak butterfly**, *N. antiopa* (L.), is a widespread species, occurring throughout the subarctic regions of North America. The larvae, commonly known as **spiny-elm caterpillars**, feed on elm, willow, poplar, and hackberry, and are sometimes abundant locally, especially on shade and ornamental trees and along fence rows. Adults are black-bodied and have wingspreads of 60 to 80 mm. The upper wing surface is dark reddish-brown except for a broad, creamy-yellow border that contains a row of blue spots. Full-grown caterpillars (fig. 64) are black, with a scattering of white dots and a red dot on the dorsum of abdominal segments one to seven. The head is covered with tubercles; the body, with many large, branched spines.

Courtesy Rocky Mt. For. & Range Exp. Stn.

Figure 64.—Larva of the mourningcloak butterfly, *Nymphalis antiopa*.

Winter is spent in the adult stage, and the adults appear in early spring. Eggs are deposited in clusters around small twigs. The larvae feed gregariously until almost full grown and usually defoliate one branch before moving to another. Chrysalids are formed in June or early July. Adults soon appear and lay the eggs for a second brood. Larvae of this generation are present until September. They then pupate and the adults emerge to hibernate. There are one or two generations per year, depending on location.

The mourningcloak butterfly is of minor importance in the forest, but is sometimes injurious to shade and ornamental trees. Infestations can be controlled by cutting and burning infested twigs and small branches.

The **viceroy**, *Basilarchia archippus* (Cramer), occurs over most of the United States and feeds on poplar and willow. The adult resembles the well-known monarch butterfly, *Danaus plexippus* (L.), but differs by being slightly smaller, having a narrow black line across the hindwings and only a single row of white spots in the black marginal band of the wings. The full-grown caterpillar is about 37 mm long. The head is large, pale green, and bilobed. Body segments one and two are pinkish to brownish; segments three to six and the sides of seven are brownish or greenish; the tops of segments seven and nine and nearly all of eight are pale pinkish or whitish; and the top of nine and nearly all of the last three are brownish or greenish. There are two barbed, club-shaped, brown tubercles on top of the second thoracic segment and two smaller ones armed with spines on the top of the other segments. There are two generations per year. The two related species, *B. arthemis* (Drury), the **white admiral**, and *B. astyanax* (F.), the **red spotted purple**, are found on poplar, willow, birch, black cherry, apple, and basswood. The caterpillars are similar in appearance to those of *B. archippus.*

Asterocampa clyton (Boisduval & LeConte), the **tawny emperor**, occasionally seriously defoliates hackberry in the Lake States *(714)*. Full-grown caterpillars are 25 to 37 mm long. The body is greenish except for a yellow stripe down the back and a deep blue, yellow-bordered stripe on each side. The head is armed with branches, antlerlike spines, and there are two projections at the posterior end of the body. *A. celtis* (Boisduval & LeConte), the **hackberry butterfly**, is also occasionally abundant on hackberry in the Lake States. The caterpillar is greenish with a row of yellow dots down the back and three yellow lines along each side. Otherwise, it resembles the caterpillar of *A. clyton.*

Family Megalopygidae
Flannel Moths

The bodies of flannel moths are covered with dense coats of scales and long crinkly hairs. The larvae are also densely covered with long soft hairs, with an intermingling of venomous spines. Females deposit their eggs in small batches, usually on leaves, and cover them with hairs from the abdomen.

The **puss caterpillar**, *Megalopyge opercularis* (J. E. Smith), occurs throughout the Southern States where it feeds on various deciduous trees and shrubs. Forest and shade trees commonly infested include oak, elm, hackberry, maple, and sycamore. The adult moth is yellowish brown, with brownish spots on the wings, and has a wingspread of about 25 mm. The wings bear long, wavy, white hairs, especially along the veins. The larvae are densely clothed with long yellow and reddish-brown or mouse-gray hairs. The hairs on the rear end are taillike.

Young larvae feed gregariously on the surface of the leaf and skeletonize it. Older larvae devour the entire leaf. Serious infestations have been recorded in Florida and Texas. Several thousand hectares of turkey oak were defoliated during an outbreak

in Florida in 1966. Generally speaking, however, the species is most important as a pest of people, because of its poisonous spines *(114)*. There may be two generations per year in the more southerly portions of its range. Winter is spent as a pupa in a cocoon spun some place on the host tree. Handpicking larvae, wearing gloves, is a common control practice. The tachinid parasite, *Carcelia lagoae* (Townsend), is sometimes abundant in Texas infestations.

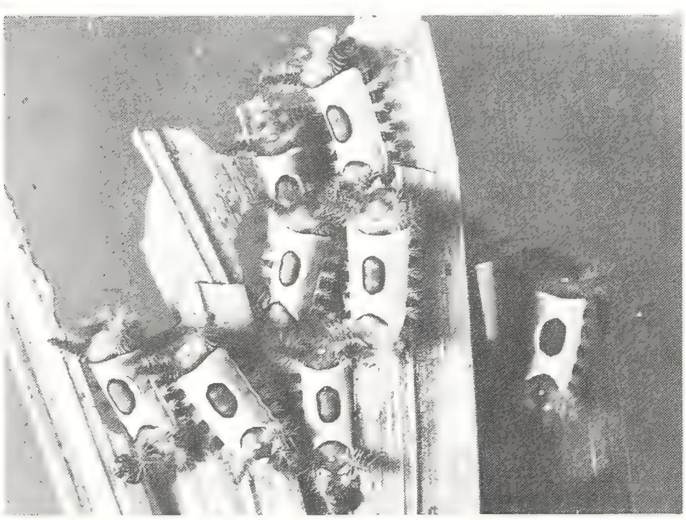
The **crinkled flannel moth**, *Lagoa crispata* (Packard), occurs throughout the eastern half of the United States and feeds on a wide variety of plants, including oak, locust, birch, cherry, and apple. According to some reports, it occurs most commonly in the northern parts of its range; however, it has completely defoliated shin oak over several hundreds of hectares of rangeland in Texas. The adult is cream colored, with black wavy lines and brownish, crinkled hairs on the forewings. Full-grown larvae are oval and about 25 mm long. The body is covered with long, silky brown hairs that meet in the form of a ridge along the back and then slope off, rooflike, on each side. Winter is spent in the pupal stage in a cocoon. The cocoon is unique in being urn-shaped and having a flat, hinged, circular lid that is lifted as the moth emerges. The stings produced by spines on the larvae of this species apparently are less severe than those produced by related species *(114)*.

Norape ovina Sepp feeds on redbud, silktree, and beech from New Jersey and southern Pennsylvania southward. The adult is a pure white moth with a small amount of crinkly hair. The larvae are spotted and sparsely clothed in tufts of hair.

Family Limacodidae
Slug Caterpillar Moths

Limacodid larvae are sluglike in appearance. The head is concealed in the thorax, the thoracic legs are small, and the prolegs are replaced by sucking discs. Pupation occurs in dense, brownish, oval, silken cocoons spun between leaves or attached to twigs. Each cocoon has a hole covered by a lid at one end through which the adult emerges.

The **saddleback caterpillar**, *Sibine stimulea* (Clemens), is widely distributed in the Eastern and Southern United States and feeds on a wide variety of trees and ornamental plants. The larva is brownish except for a green patch, which resembles a saddlecloth, on the middle of the back. In the middle of this patch is an oval, purplish-brown, saddlelike spot. The body is armed along the sides with fascicles of poisonous spines, and has a pair of spiny tubercles at each end (fig. 65).



Courtesy Conn. Agric. Exp. Stn.

Figure 65.—Larvae of the saddleback caterpillar, *Sibine stimulea*.

The **hag moth**, *Phobetron pithecium* (J. E. Smith), feeds on various deciduous trees and shrubs. The larvae are brown, about 10 mm long, and each bears nine pairs of lateral brown processes. The third, fifth, and seventh pairs are long, curved and twisted, and are suggestive of the disheveled locks of a "hag." These processes are clothed with stinging hairs.

The **oriental moth**, *Cnidocampa flavescens* (Walker) (fig. 66), an introduced species first recorded in this country near Boston in 1906 *(223)*, is still confined to eastern Massachusetts. The adult has a wingspread of 30 to 42 mm. Full-grown larvae are about 22 mm long and marked with yellow, blue, green, and purple. The larvae feed on a large number of tree species, including Norway and planetree maples, sweet birch, cherry, apple, pear, plum, oak, aspen, willow, honeylocust, hickory, and hackberry.

F-519528

Figure 66.—The oriental moth, *Cnidocampa flavescens:* Upper, adults and cocoons; middle, a defoliated Norway maple; lower, full-grown and newly hatched larvae.

Adults deposit their eggs either singly or in groups in the undersides of leaves. Young larvae feed on the lower epidermis of the leaves; older ones consume all but the larger veins. A full-grown larva forms a cocoon by spinning a network of threads around itself and attaching them to the bark in the forks of limbs or twigs. Later it secretes a fluid that fills the spaces between the threads and hardens. Winter is spent as a prepupa in the cocoon. People suffer severe skin irritation when they come into contact with the larva's venomous spines. The tachinid parasite, *Chaetexorista javana* Bauer & Bergenstamm, was imported from Japan against this species in 1929 and 1930 and has exerted a considerable degree of control.

Prolimacodes badia Hübner feeds on various hardwoods such as oak, beech, and black cherry in the Northeastern States and southern Canada. It has also been observed feeding on maple in North Carolina. *P. scapha* Harris feeds on pin cherry and blackgum in Massachusetts and New Jersey. *Isa textula* Herrich-Schäffer feeds on Norway maple and oak, *Packardia geminata* Packard on pin cherry, and *Tortricidia flexuosa* Grote on oak, gray birch, and pin cherry in the New England States.

Family Pyralidae

Several subfamilies, sometimes listed as separate families, of the Pyralidae contain species of interest in forestry. These include the Pyraustinae, Epipaschiinae, and Phycitinae.

Subfamily Pyraustinae
Pyraustine Moths

The **grape leaffolder**, *Desmia funeralis* (Hübner), an important pest of grape, both cultivated and wild, occurs in eastern North America and along the West Coast. It also feeds on Virginia creeper. The body of the adult is black except for a white band on the abdomen of the male and two white bands on the abdomen of the female. The forewings and hindwings are black with white spots and have coppery reflections. The wingspread is about 25 mm. The larvae live in tubes formed by rolling over the edges of leaves and tying them with silk. When they are fully grown, larvae are covered with sparse, fine, yellow hairs, are translucent yellow-green, and are 18 to 25 mm long. The winter is spent in the pupal stage inside the larval tube. There are two generations per year in the South.

The **basswood leafroller**, *Pantographa limata* Grote & Robinson, occurs on basswood in southern Canada and throughout the Eastern United States. The adult is yellowish white, with an abundance of olive or dull-brown markings, and has a wingspread of about 37 mm. Full-grown larvae are bright green, except for black heads and black cervical shields, and are about 25 mm long. Adults appear during June and July; larvae are present from July to September. Each larva rolls the apical half or more of a leaf into the form of a tube in which it lives (fig. 67). Full-grown larvae spend the winter in cocoons constructed by folding a part of a leaf. The folded leaf drops to the ground with other leaves. Although frequently abundant, this species does not seem to cause serious damage.

Phlyctaenia coronata (Hufnagel), the **elder leaftier**, larvae feed as leafrollers on the leaves of American elder in the Northeastern States. The adult is brown except for the presence of creamy-white spots and streaks, and has a wingspread of 22 mm. Full-grown larvae are translucent, whitish or pinkish, and about 18 mm long. Winter is spent as a prepupa in a hibernaculum usually spun in the hollow stems or pith of elder. There may be two generations per year. This species occasionally causes serious defoliation.

Subfamily Epipaschiinae

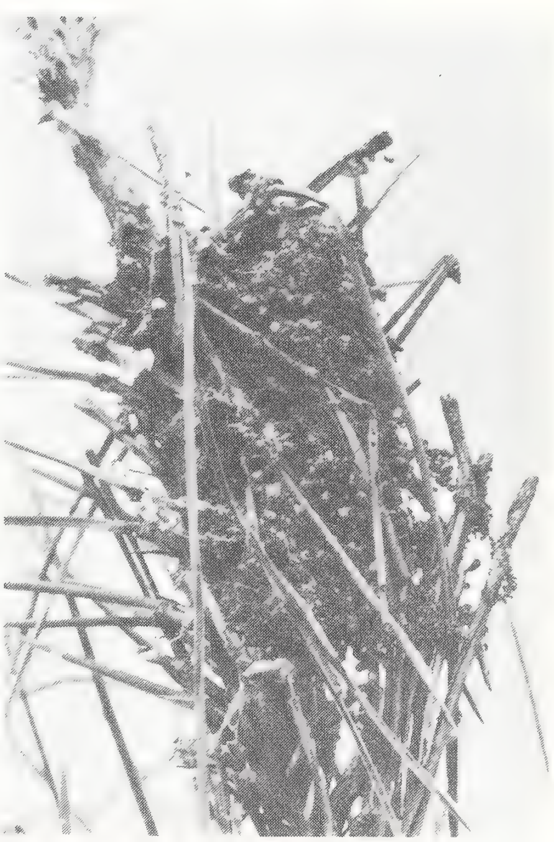
The **pine webworm**, *Tetralopha robustella* Zeller, occurs in southern Canada and throughout most of the eastern half of the United States. Its food plants include several species of pines: jack, red, eastern white, Scotch, pitch, Virginia, shortleaf, longleaf, loblolly, and slash. Jack pine is preferred in the Lake States and adjacent parts of Canada. In the Northeast, pitch pine is preferred. The adult has a wingspread of about 25 mm. The basal part of the forewing is purple-black, the central part grayish, and the outer part blackish. Full-grown larvae are yellowish brown, with two dark-brown longitudinal stripes on each side, and are about 18 mm long.

Adults are present from June to August and deposit their eggs on pine needles. Young larvae mine the needles; older ones live in silken tubes that extend through globular masses of brown, coarse frass webbed together by strands of silk (fig. 68). These masses, which are found on the twigs, enclose the needles upon which the larvae feed, and range in length from about 8 to 13 cm. Pupation occurs in a cell in the soil. In the northern part of its range, there is usually one generation per year; in the South there may be two *(1240)*.

The pine webworm is often troublesome in pine plantations. Young seedlings up to 0.6 m tall are sometimes completely defoliated and killed by the larvae in a

F-519529

Figure 67.—Apical portion of leaf rolled into a tube by a larva of the basswood leafroller, *Pantographa limata*.



F-532810

Figure 68.—Web nest of the pine webworm, *Tetralopha robustella*, on slash pine.

single nest. Ugly nests on the twigs and branches of young pines being grown for the Christmas tree trade sometimes make it impossible to sell them.

Tetralopha asperatella Clemens, the **maple webworm**, occurs in southeastern Canada and throughout the Eastern United States. The larvae feed on the foliage of various hardwoods such as sugar, red, and mountain maples, oak, elm, beech, quaking aspen, and willow. The moth is powdery gray, with the outer half of the forewing somewhat lighter. Full-grown larvae range from pale yellow through shades of green to brown or black and are about 25 mm long. On sugar maple in Wisconsin, eggs are laid on leaves partly rolled by other insects. When the larvae hatch they feed on these leaves as skeletonizers; older larvae web together groups of leaves, sometimes including all of the leaves on a branch in a web (fig. 69). Heaviest infestations apparently occur in the more open portions of the crowns of trees growing in the most exposed positions in the stand. When the larvae become full grown, they leave the nest and drop to the ground on strands of silk. The winter is spent as a prepupa in a cocoon spun in the duff on the ground. There appears to be only one generation per year *(483)*.

F-519532

Figure 69.—Characteristic nest of *Tetralopha asperatella* on oak.

This species had never been considered economically important until it was shown to be a major factor leading to the development of "maple blight," a condition responsible for killing thousands of valuable sugar maples in Wisconsin during the late 1950's.

Other species of *Tetralopha* that occur in the Eastern United States are *T. militella* Zeller feeding on sycamore; and *T. melanogrammos* Zeller, on sweetgum. Another species identified only as being near *T. asperatella* is sometimes abundant locally on beech in New England. The larva is yellowish green and has two pale, brownish stripes running down the back.

Subfamily Phycitinae

The subfamily Phycitinae contains many important tree-infesting species. The larvae differ considerably in their habits. Some feed in rolled or folded leaves; some

construct cases of silk, or frass and silk, and feed from inside them; at least one is a predator of scale insects; and many feed as borers in shoots, bark, roots, cones, nuts, or fruits. Members of the subfamily are rather difficult to identify because of the variability of many of their distinguishing characters.

The **pecan leaf casebearer**, *Acrobasis juglandis* (LeBaron), occurs from southern Canada to Florida and Texas, and the larvae feed on the buds, flowers, and leaves of walnut, butternut, and pecan. The adult is a grayish-brown moth with the forewings black at the middle of the costa and reddish-brown near the middle of the inner margin, a black raised-scale ridge is also present on the forewings, and the head and thorax of the male are distinctly white above. Wingspread is 14 to 17 mm. Full-grown larvae are mostly olive green to dark olive green and about 16 mm long. The larvae feed during two growing seasons. The first summer, they feed on the lower surfaces of leaves. They spend the winter in small cases attached to buds or twigs. The following spring, they resume their feeding by eating into bud after bud and constructing new cases as necessary. When the larvae become about half grown, they move onto the underside of the rachis. The rachis and base of the adjacent leaflets are notched and a tube of silk is formed and fastened to the notch in the rachis. The leaflets are pulled down about the silk tube and eaten. This, plus the injury to the buds, often results in serious damage to infested trees *(484, 921)*.

Acrobasis caryivorella Ragonot occurs in southern Canada and throughout the Eastern United States and the larvae feed on the foliage of hickory, walnut, and pecan. The forewings of the adult are black with indistinct patches of gray; a black raised-scale ridge is also present on the forewings. The wingspread is about 20 mm. The larvae are purplish green and about 19 mm long. In the spring, they feed by boring into new shoots that they tie together with silken threads. Full-grown larvae construct oval cocoons in which they pupate. Several generations occur each year. Generations occurring after the spring generation feed on silked-together leaflets. In Florida and Texas, there are probably three or four generations per year. This species has seriously damaged pecan seedlings in nurseries in Florida and Texas.

The **pecan nut casebearer**, *A. nuxvorella* Neunzig, occurs from North Carolina and southern Illinois to Florida and Texas. Its host tree is pecan *(920)*. The adult is mostly dark brown with a dark-brown raised-scale ridge on the forewings, and has a wingspread of 12 to 19 mm. Mature larvae are mostly purplish brown with greenish undertones and are about 12 mm long. Winter is spent in the larval stage in a small case near the base of a bud. Later, larvae bore into tender shoots, causing them to become stunted and distorted. Larvae of the second generation bore into newly set nuts, destroying from two to five nuts each. Larvae of later generations feed in the large nuts or on the shucks. There are three or four generations per year in the South.

Many other species of *Acrobasis* occur on forest and shade trees in the Eastern United States. The **birch tubemaker**, *A. betulella* Hulst, is common, feeding on the foliage of various species of birch, particularly paper birch in the Northern United States and southern Canada; *A. betulivorella* Neunzig occurs on river birch in the Southeastern United States; *A. rubrifasciella* Packard, the **alder tubemaker**, feeds on foliage of alder; *A. indigenella* (Zeller), the **leaf crumpler**, is associated with hawthorn foliage; *A. demotella* Grote, the **walnut shoot moth**, bores in shoots of walnut, hickory, and pecan; *A. exsulella* (Zeller) occurs in buds and between leaves of hickory and pecan; *A. elyi* Neunzig bores into, and galls, the rachis of hickory leaves; *A. carpinivorella* Neunzig feeds on the leaves of American

hornbeam. Details on the immature forms and biology of these and other species of *Acrobasis* are available *(921, 922)*.

The genus *Dioryctria* has Holarctic distribution, and the larvae of all species are borers in conifers. Many are highly injurious to seeds and cones *(360, 547)*. The larval habits of some of the more widely distributed species are quite variable. This suggests that more than one species is involved in certain cases. This can be established only through further taxonomic and biological investigations. The genus has been discussed *(357, 360, 553, 897, 901, 902, 924, 925)*.

The **Zimmermann pine moth**, *D. zimmermanni* (Grote), is widely distributed in the Northern United States and southern Canada. The larvae feed in the cambial region and outer xylem under the bark of limbs and trunks of all commonly grown species of pines. The adult has forewings of gray blended with red-brown and marked with transverse zigzag whitish and black lines; the hindwings are yellowish white. Mature larvae are variably dirty-white, pink to greenish, with prominent small black setal bases, with black muscle attachments; they are about 18 mm long.

Adults emerge from mid-July to mid-August and deposit their eggs at the edges of wounds, on resin masses, in bark crevices, or on terminal buds. Hatching occurs in about 8 to 10 days and the young larvae, without feeding, enter bark recesses and spin hibernacula. Here they remain until the following spring. Feeding begins in May or June, first in the bark, then by tunneling in the cambium area of new growth on terminals or laterals. Damaged terminals usually become "fish-hooked" and turn yellowish green. Toward the end of June, the larvae leave the new growth and tunnel beneath the bark in the whorl area, girdling branches and leaders. Pupation occurs in resin masses or in the tunnel. Dead tops, dead branches hanging on trees (fig. 70), and burllike growths on trunks above girdled whorls and pitch masses (fig. 71) are evidence of attack. Infested trees tend to be attacked again and again, thus becoming so-called brood trees *(1017)*.

F-492959

Figure 70.—Damage to young pine by the Zimmermann pine moth, *Dioryctria zimmermanni*.

F-492960

Figure 71.—Burllike growths on trunk above girdled whorl, a sign of attack by Zimmermann pine moth.

Zimmermann pine moth damage has been especially serious in Christmas tree plantations of Scotch, red, and Austrian pines in the North Central States and southern Canada.

The remaining eastern *Dioryctria* species are known primarily for their injury to cones although other tree parts may be infested *(360)*.

The **southern pine coneworm**, *D. amatella* (Hulst), occurs throughout the Southeast from Virginia to Florida and westward to Texas. In addition to cones, it infests male flowers, shoots, fusiform rust cankers, *Cronartium quercuum* (Berk.) Miyabe ex Shirai f. sp. *fusiforme*, and southern cone rust, *C. strobilinum* Hedgc. & Hahn, infested cones and tree wounds of southern pines, particularly of longleaf, slash, and loblolly pines. The adult (fig. 72) has a wingspread of 27 to 32 mm; the forewing is dark brown, nearly black, with contrasting white patches and zigzag lines. Mature larvae are brownish to purplish above, pale whitish to greenish below, with black muscle attachments; they are about 25 mm long.

F-532840

Figure 72.—Adult of the southern pine coneworm, *Dioryctria amatella*.

First-stage larvae overwinter under bud or bark scales; occasional larger larvae overwinter in damaged cones. In longleaf pine, overwintered larvae usually feed first upon flowers, both male and female, then enter shoots or second-year cones. The larvae in shoots may mature there or migrate to second-year cones. In slash and loblolly pines, overwintered larvae more frequently occur in fusiform rust cankers where they complete development. Later overlapping generations occur mainly in second-year cones of all host pines. Pupation occurs within host materials. This species is frequently reported as the cause of heavy cone losses of southern pines.

Dioryctria abietivorella (Grote), the **fir coneworm**, ranges across Canada and the adjoining Eastern and Western United States. It is a coneworm that also infests buds and twigs, and occasionally feeds under the bark. It occurs on a variety of conifers including the eastern spruces and firs and red, eastern white, and jack pines. The moth has blue-gray forewings crossed by diffuse, pale zigzag lines; the hindwings are pale gray. Wingspread is from 20 to 30 mm. The mature larva is reddish carneous to amber- or purplish-brown with indistinct darker dorsal and subdorsal lines, and is from 15 to 25 mm long *(791, 897)*.

Damage is similar to that of the spruce coneworm. Prepupal larvae or pupae overwinter and produce early season moths in June and July. However, some larvae apparently mature and pupate and the moths emerge in late summer and fall. These

give rise to a group of overwintering larvae. Essentially, however, a single generation occurs each year *(759)*.

The **spruce coneworm**, *D. reniculelloides* Mutuura & Munroe, occurs throughout the forested regions of Canada and in the Northern and Western United States. It feeds primarily upon cones and associated vegetative parts of white spruce and various other spruces and firs but also has been reported from other conifers within its range. The moth has dark-gray forewings strongly shaded blackish and crossed by distinct white zigzag lines. The hindwings are dusky with an obvious paler, diffuse postmedial (outer) crossband. The wingspread is 22 to 27 mm *(901)*. Mature larvae are pale yellow with distinct brown longitudinal stripes and are about 17 mm long *(791)*.

In Canada adults are present from late June to August. Eggs are laid in bark crevices and similar niches. The first instars diapause over winter. In spring they first mine needles then bore buds, staminate flowers, cones, or shoots. Masses of webbed frass enclose the food material. During certain years this coneworm takes a heavy toll of white spruce cones *(805)*.

The **blister coneworm**, *D. clarioralis* (Walker), occurs throughout the South and northward into coastal Massachusetts. It infests vegetative buds, male bud clusters, conelets, and cones of pines including longleaf, slash, loblolly, and shortleaf. Adults have blended brown and black forewings marked with wide, nearly black transverse bands near the base; wingspread is from 22 to 29 mm (fig. 73). Larvae are yellowish brown to brownish orange, often heavily suffused with gray; they are about 18 mm long. This coneworm was the most common coneworm found in cones of shortleaf and loblolly pines in Arkansas in 1960 *(1367)*, but southwide seems to be of lesser importance.

Winter is spent in the developing larval stage in buds or conelets. Flowers, cones, and buds are bored into during the spring, then succeeding generations infest buds, shoots, conelets, and occasional cones. A characteristic of damage by this species is the presence of a resin-coated silk blister over the entrance hole where ejected frass accumulates. Pupation occurs outside the hollowed-out food material on a twig or cone stalk in silken cocoons covered with bits of twig scales. Normally three generations per year occur in the South.

The **webbing coneworm**, *D. disclusa* Heinrich, occurs in southern Canada and throughout the Eastern United States. It infests cones of red, jack, and Scotch pines in the Northern States and cones of Virginia, loblolly, shortleaf, and longleaf pines

F-494452

Figure 73.—Adult of the blister coneworm, *Dioryctria clarioralis*.

in the South. The adult has forewings of bright yellow to orange, shaded red-brown with sharp white crosslines and markings, and has a wingspread of 17 to 29 mm. The larvae vary from olive green to buff. Northern larvae are small, slender, and from 14 to 18 mm; southern larvae are robust and from 20 to 25 mm long.

In the North, winter is spent as first-stage larvae in hibernacula beneath bark scales of branches. Young larvae infest staminate flowers in the spring then enter and tunnel in second-year cones as third to fourth instars *(759)*. In the South partly grown larvae have been reported to feed and overwinter in conelets *(925)*, but in northern Georgia no cone damage was observed until spring when third-stage larvae infested young second-year cones without evidence of prior conelet boring.

Infested cones are hollowed and have characteristic masses of tightly webbed frass over the entry holes. Pupation occurs in the damaged cones, and adults emerge from late May (South) through July (North). A single generation occurs each year. Damage by the webbing coneworm is generally sporadic; however, serious infestations and cone losses were experienced in loblolly pine seed orchards from 1978 to 1982 throughout the South. Pheromone-baited traps have been successful in trapping adults to determine population levels and periods of activity *(288)*.

The **baldcypress coneworm**, *Dioryctria pygmaeella* Ragonot, occurs in the Eastern United States. It infests the cones of baldcypress and pondcypress from Maryland to Florida. In northern Florida it has destroyed more than 75 percent of a single year's crop. There are three complete generations in its southern range *(839)*.

Several *Dioryctria* species of importance in the Southeast have only recently been described *(547, 902)*; previously these were often either misidentified or referred to species groups in the literature. These include: the **south coastal coneworm**, *D. ebeli* Mutuura & Munroe, limited to the lower Southeast from southern Georgia and Florida westward along the Gulf area. It infests slash, longleaf, and loblolly pines and also occurs on pondcypress. The moth (fig. 74) is similar to *D. abietivorella* and has a wingspread of about 20 mm. Mature larvae are brown to purplish and about 15 to 20 mm long. In the spring this coneworm infests conelets infected by cone rust, *Cronartium strobilinum* Hedgc. & Hahn. Throughout the summer repeated generations attack second-year cones, both intact and damaged. Fall infestations occur in fusiform cankers or terminal buds where larvae mature over winter. Larvae drop from feeding sites to pupate, apparently in soil litter. This species is periodically common, but its affinity to diseased or damaged cones reduces its impact on cone crops *(357)*.

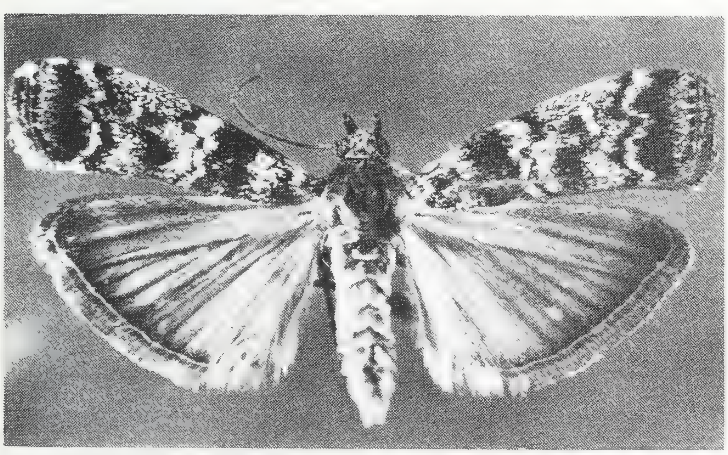


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Figure 74.—Adult of the south coastal coneworm, *Dioryctria ebeli*.

Dioryctria merkeli Mutuura & Munroe, the **loblolly pine coneworm**, occurs throughout the Southeast and northward to Maryland. It infests flowers, shoots, and cones of loblolly, slash, and longleaf pines, and occasionally other southern pines. The moth resembles *D. zimmermanni* but is duller in color and the hindwings are a light gray-brown. Wingspread is about 25 to 30 mm. The mature larva is purplish black above, deep blue-green below, with black muscle attachments, and is 18 to 25 mm long. In early spring, small larvae infest male and female flowers, then soon migrate to shoots or second-year cones. In slash and longleaf pines such larvae may mature in shoots; in loblolly they migrate to second-year cones. Mature larvae aestivate in dead shoots and cones where they pupate and emerge as adults in August and September. Larvae from this generation overwinter under bark or bud scales as nonfeeding first instars. A single generation occurs yearly. This species periodically causes extensive cone loss in loblolly pine *(1365)*.

The **mountain pine coneworm**, *D. yatesi* Mutuura & Munroe, attacks second-year cones of Table Mountain pine. It ranges throughout the Appalachian Mountain region from Pennsylvania to Georgia *(547, 902)*.

Dioryctria taedae Schaber & Wood, the **Atlantic pine coneworm**, attacks loblolly pine cones in Maryland and occurs sparingly in the Southeast *(1057)*.

Dioryctria resinosella Mutuura resembles *D. zimmermanni* but feeds on red pine shoots and cones in the Northeast, Lake States, and southern Ontario *(759, 899)*. Mature larvae are gray to green with black muscle attachments, and about 15 mm long.

The **locust leafroller**, *Nephopteryx subcaesiella* (Clemens), occurs from southern Canada and Maine to North Carolina and westward to Colorado. The larvae feed inside tied-together leaves of black locust, other locusts, and wisteria. The adult is dark gray with some reddish scales at the wing base, and has a wingspread of about 25 mm. Mature larvae are about 20 mm long. The head is dark brown and the body light green, except for a darker green line from the middle of the dorsum and for three faint lines on each side. The prothorax is usually distinctly darker than the mesothorax and metathorax. The winter is spent as pupae in silken cocoons in the soil. This species is quite common at times, but is seldom injurious. *N. virgatella* (Clemens) is a leafroller on black locust. The larvae resemble those of the locust leafroller except that they are much more lightly pigmented. *N. subfuscella* (Ragonot) is a leafroller on sumac from Maine to Texas. The adult is ash gray and has a wingspread of about 22 mm. Mature larvae are yellowish green except for dark-green lines on the dorsum and sides, and are 13 to 20 mm long. Additional information on the species of *Nephopteryx* is available *(244, 315, 316, 923)*.

The **lesser cornstalk borer**, *Elasmopalpus lignosellus* (Zeller), a widely distributed species, has damaged black locust seedlings in nurseries in several southern states. Loblolly pine seedlings in nursery beds in Georgia, Virginia, and Rhode Island have also been damaged. Gall-like growths occur at points of injury on the lower stems of locust seedlings, causing them to die or break off at the ground line. The male adult is mostly ochre-yellow to light brown but the female is heavily shaded black. The wingspread is 16 to 24 mm. The forewings are long and narrow and marked with several black spots. Mature larvae are greenish white with interrupted longitudinal stripes of dark brown or purple. The winter is spent in the larval or pupal stage and there are up to four generations per year in the Deep South *(923, 1205)*.

The **American plum borer**, *Euzophera semifuneralis* (Walker), is widespread and attacks a wide variety of hardwoods, including plum, pin cherry, apple,

London plane, mountain-ash, walnut, persimmon, mulberry, basswood, poplar, sweetgum, and ginkgo. Serious infestations have occurred on young London plane trees in newly developed areas on Long Island. The larvae bored in the trunks and larger branches, and were associated with a canker condition *(644)*.

Euzophera ostricolorella Hulst has been recorded from Long Island to Georgia and westward to Ohio, Kentucky, Tennessee, and Louisiana. Its preferred host appears to be yellow-poplar, but it also attacks magnolia. Heaviest infestations on yellow-poplar are found at the base of trees over 25 cm in diameter *(537)*. Attacks above a height of 60 cm on the trunk are rare. The larvae feed in the inner bark, excavating tunnels which extend both above and below the ground line. Winter is spent in the pupal stage in the tunnel. There appears to be one generation per year in the North and two per year in the South. Trees of all sizes may be killed by heavy infestations.

Euzophera magnolialis Capps has been observed damaging or killing magnolia seedlings in Florida nurseries. The adult has a wingspread of about 25 mm and the forewing is purplish brown with black terminal dots. Full-grown larvae are white and flattened, they taper toward the rear, and are about 28 mm long. Attacks occur at the base, the larvae tunneling in the lower centimeters of the trunk and in the larger roots entering the crown. Heavily infested trees may be girdled and killed *(196)*.

Canarsia ulmiarrosorella (Clemens) occurs in southern Canada and throughout the Eastern United States. The larvae feed on the leaves of elm that they web together with silk. The adult has a wingspread of 15 to 20 mm. The forewings are gray-dusted white and crossed by dark gray or blackish wavy lines. Mature larvae are green, sparsely hairy, and about 18 mm long. Winter is spent in the pupal stage, and there are two generations per year. This species is sometimes abundant enough to attract attention, but is seldom injurious.

Moodna ostrinella Clemens is rather widely distributed in southeastern Canada and the Eastern United States. In Canada, the larvae have been found in second-year pine cones damaged by other insects. They have also been found in damaged pine cones in Arkansas; in sumac heads in New York, Pennsylvania, and Texas; and in fusiform rust cankers and in dead and diseased cones on pines in Florida. Full-grown larvae vary from yellow with a greenish tinge to purplish brown with bright orange-brown heads, and are about 8 to 10 mm long.

Actrix nyssaecolella (Dyar) is a leaffolder of tupelo from western Pennsylvania to New Jersey and Massachusetts and south to North Carolina. The adult is powdery gray and has a wingspread of 18 mm. Full-grown larvae are black with yellow heads. Winter is spent in the pupal stage, and larvae are present from May to August.

Laetilia coccidivora (Comstock) larvae feed on various scale insects. According to some reports, it has aided materially in the control of outbreaks of the pine tortoise scale. It has been recorded from Pennsylvania and Ohio to Florida and Texas.

Family Geometridae
Geometrid Moths

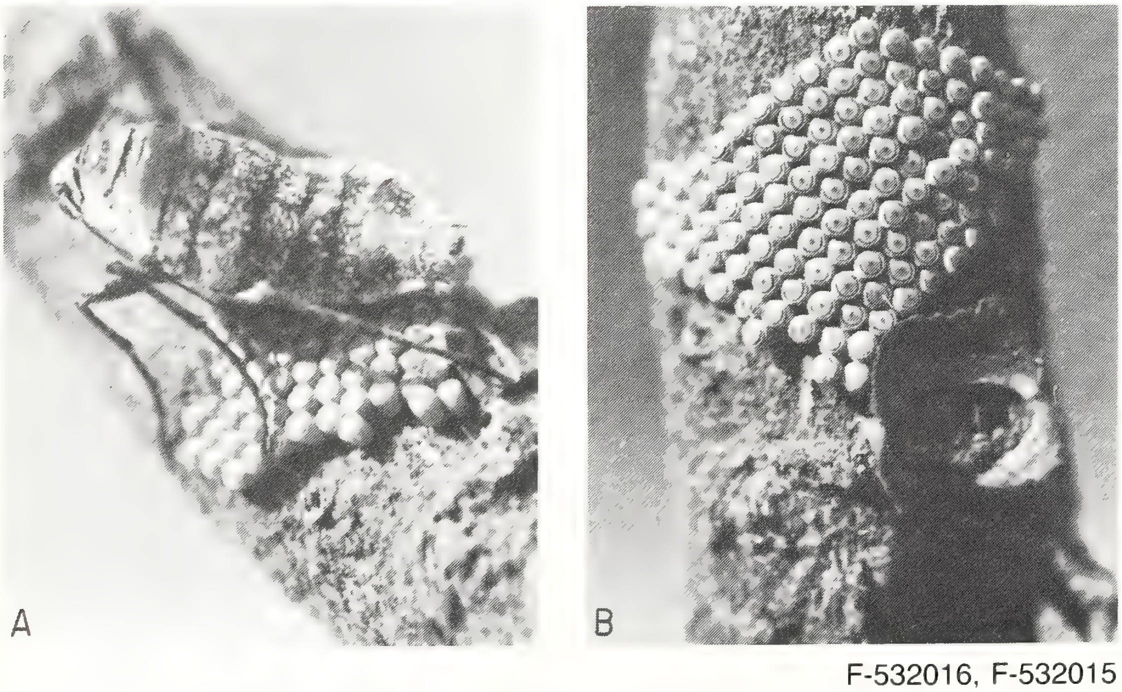
This is one of the largest families in the order Lepidoptera, and approximately 1,200 species occur in the United States and Canada alone. The larvae are easily distinguished by their peculiar method of locomotion, which consists of bringing the rear end up to the thoracic legs, forming a loop of the body, and then extending the whole body forward. This characteristic, which results from the absence of

prolegs near the center of the body, has given rise to a number of common names for the group such as geometers, measuring worms, inch worms, loopers, cankerworms, and spanworms. The larvae of many species have the interesting habit of standing nearly erect on the posterior prolegs when disturbed. Motionless in this position, they are almost indistinguishable from small twigs or spurs. With the exception of several Hawaiian species, which are predators of fruit flies, all members of the family are foliage feeders.

Archiearis infans (Möschler) occurs from coast to coast in southern Canada and in the Northern States south to Pennsylvania. Its hosts are paper and gray birches. The adult has cryptic forewings and orange and black hindwings, and has a wingspread of about 25 mm. Mature larvae are green to reddish brown and about 25 mm long. Two fine yellowish lines run the length of the dorsum, and there are two similar lines plus a broad subspiracular stripe on each side. Larvae are present from May to July, and winter is spent in the pupal stage.

The **fall cankerworm**, *Alsophila pometaria* (Harris) (fig. 75), occurs from the Maritime Provinces to Alberta in southern Canada, and throughout the Eastern States south to Georgia and west to Missouri and Montana *(397)*. Its hosts are elm, apple, hickory, maple, ash, beech, boxelder, basswood, cherry, and the oaks *(399)*. The male moth is brownish gray and has a wingspread of 25 to 35 mm. The forewings are rather glossy with purplish reflections and are crossed by two faint, jagged, whitish bands. The hindwings are grayish brown, and each has a faint discal dot. Female adults are wingless and about 12 mm long. Full-grown larvae vary from very light green to very dark brownish green and are about 25 mm long. The head and anal segment vary from pale green to almost black, and are sometimes mottled. A median, longitudinal, black stripe extends down the back of the darker larvae. Light-green larvae have longitudinal white lines. These color forms are associated with population density, with the darker larvae occurring in denser populations *(334)*. There are three pairs of prolegs—a very small pair on the fifth abdominal segment and larger pairs on the sixth and anal segments.

The fall cankerworm spends the winter in the egg stage, and hatching occurs from mid-April to early May. Young larvae skeletonize the young leaves at the tips



F-532016, F-532015

Figure 75.—The fall cankerworm, *Alsophila pometaria*: A, adult female ovipositing; B, egg mass.

of branches; older ones devour all but the midribs or larger veins of the leaves. They become mature in 5 to 6 weeks at which time they drop to the ground and enter the soil where they pupate in tough cocoons made from silk and soil particles. Adults emerge from November to January and in some localities into the springtime, usually following some freezing weather. Reproduction is by sexual mating and a type of parthenogenesis tentatively described as gynogenesis (the genotypes are only of the female) *(866, 1067)*. Females climb the trees, mate, and deposit about 100 brownish eggs in compact, uniform rows of single layers on the trunk, smaller twigs, and branches *(397)*. There is one generation per year.

The fall cankerworm is an important pest of forest and shade trees. Outbreaks occur periodically and sometimes cover large, forested areas. Shade trees in urban areas are subject to heavy infestation and may be seriously damaged. Severe infestations in recreational areas are particularly annoying. Natural control by the egg parasite, *Telenomus alsophilae* Viereck, is a major factor in the decline of fall cankerworm populations *(398)*.

The **Bruce spanworm**, *Operophtera bruceata* (Hulst), occurs from coast to coast in Canada and from New England to the Lake States. In eastern America its preferred hosts are sugar maple, quaking aspen, willow, and beech, but many other hardwoods such as paper birch, red oak, pin cherry, common chokecherry, alder, and serviceberry are also attacked. Serious outbreaks have occurred in both the United States and Canada.

Female moths are light brownish-gray and practically wingless. Males are light brown and have fully developed wings; their forewings are semitransparent, banded with brown or gray, and have a wingspread of 25 to 30 mm. Full-grown larvae may vary from bright green to dark brown and have three narrow yellow stripes on each side; larvae are about 18 mm long.

In Canada, winter is spent in the egg stage and hatching occurs in early spring. The larvae feed either openly on leaves or within the shelter of leaves loosely rolled and webbed together with silk. In heavily infested stands, trees are sometimes literally festooned with this silk. Pupation occurs in thin, silk cocoons in the soil or duff. Adults appear in the fall. The female climbs trees and deposits eggs singly in bark crevices, under loose bark, or in other sheltered locations on the tree *(162)*. A polyhedrosis virus disease has occurred commonly in New Brunswick infestations.

The **winter moth**, *O. brumata* (L.), an introduced species known to have been present in Nova Scotia since about 1930, now occurs also on Cape Breton and Prince Edward Islands, and in the Pacific Northwest. Although it was originally found in the United States at Portland, Oreg., in 1958, the male specimens were previously misidentified and not correctly determined until 1978. The female moth has a dusky-brown to silver-gray body with occasional irregular black spots and is practically wingless. Males have fully developed wings with a wingspread of 27 to 30 mm. The body is dusky brown with black spots and the forewings are dusky brown with obscure markings.

The most common hosts are apple, northern red oak, American elm, red maple, basswood, and eastern hophornbeam, but a number of other hardwoods are also attacked, such as poplar and willow. Persistent severe attacks result in thin tops, dead twigs and branches, and ultimately the death of trees. Severe defoliation of principal host trees often occurs in Nova Scotia.

Winter is spent in the egg stage and hatching occurs from late April to late May. Young larvae feed first on opening buds and on the undersides of developing leaves. Older larvae feed inside loose leaf rolls. When larvae become mature, they drop and

enter the ground where they pupate in earthen cells at a soil depth of 5 to 12 cm. Pupation occurs during late June and early July, and the pupae remain in their cells during the remainder of the summer and fall. Adults appear from late October to mid-December. The females climb tree trunks or other objects near their emergence sites and deposit their light-green eggs in bark crevices, under lichens on the trunks or branches, or in other places that afford suitable shelter *(270)*. The population dynamics of the winter moth has been investigated *(382)*, and a key is available to distinguish this defoliator from associated species of *Operophtera*, *Erannis*, and *Alsophila (403)*.

Two imported parasites, the tachinid, *Cyzenis albicans* (Fallén), and the ichneumonid, *Argypon flaveolatum* (Gravenhorst), have provided successful biological control of the pest in Nova Scotia *(383)*.

The genus *Eupithecia* contains a large number of species, a number of which occur in forests of the Eastern States and eastern Canada. *E. palpata* Packard, the **small pine looper**, occurs on various species of pine, especially eastern white and jack; *E. luteata* Packard, the **fir needle inchworm**, feeds on various spruces, particularly white, and other conifers, especially balsam fir and larch; *E. filmata* Pearsall, the **early brown looper**, is found on a wide variety of conifers, especially white spruce and balsam fir; and *E. transcanadata* MacKay, the **small conifer looper**, that feeds on a wide variety of conifers, especially white spruce, black spruce, and balsam fir *(738)*.

Hydria prunivorata Ferguson, the **cherry scallop shell moth**, occurs on black and occasionally other wild cherries throughout much of eastern North America. The adult has a wingspread of about 37 mm. The forewings are marked with 12 to 15 whitish, scalloped, parallel lines and a black discal dot; the hindwings are marked with 6 to 8 whitish lines. Full-grown larvae are about 20 mm long. The body is blackish above with four longitudinal yellow lines, and is straw yellow beneath. The larvae live in nests that they construct by webbing together the leaves toward the end of a branch. Heavily infested trees occasionally are completely defoliated. An egg parasite, *Telenomus* sp., is the principal mortality factor in populations that have remained at epidemic levels for 2 years or more *(1070)*.

Rheumaptera hastata (L.), the **spear-marked black moth**, feeds on paper birch, willow, and alder from Alaska east to Labrador and Newfoundland. It occurs as far south as New Mexico and North Carolina. Major areas of defoliation have been limited to interior Alaska *(1274)*. Full-grown larvae are about 25 mm long. The head is brown to shiny black; the body is dark brown to black with a row of small black dots and a few white to brick-red spots on each side. In the Northeastern States, larvae are present from June to September, and winter is spent in the pupal stage.

Lomgarapha semiclarata (Walker), the **wildcherry looper**, occurs on pin cherry in southern Canada and the Atlantic Coast States. Full-grown larvae are light green and about 18 mm long. The related species, *L. vestaliata*, (Guenée), is known to occur on cherry, mountain-ash, and birch in Maine.

Cabera erythemaria (Guenée) feeds on willow in the Northeastern States. Full-grown larvae are about 27 mm long. They are light green with a reddish stripe on each side of the head, reddish patches on the back, and a red stripe on each side of the body. Winter is spent in the larval stage. The related species, *C. variolaria* Guenée, is found on willow and quaking aspen in the Northeastern States and southwestern Canada.

Itame pustularia Guenee occurs on red maple from eastern Canada to Florida. It is occasionally abundant. It has been reported from widely scattered localities in southern Canada, and high populations have occurred in the areas of central New Brunswick that were repeatedly sprayed for control of spruce budworm *(1234)*. The adult has a wingspread of about 25 mm and is pure white except for four brownish spots on the margin of the forewing. The light-green eggs are laid singly on bark, lichens, or in litter. Eggs overwinter and larvae hatch in early spring. Young larvae are light green and closely resemble other geometrids, especially cankerworms and Bruce spanworm. Older larvae have two whitish lines down the back, bordered by yellowish-white lines; the integument is quite wrinkled. Before pupating, larvae change color from green to pink. Larvae are present during May and June.

Semiothisa signaria dispuncta (Walker), the **spruce-fir looper**, feeds on the foliage of various conifers such as eastern white pine, spruce, balsam fir, and hemlock. It has a transcontinental range. Full-grown larvae are about 20 mm long. The body is light green with brownish tinges on top, and there are two light longitudinal lines on the back. *S. granitata* (Guenée) feeds on Virginia pine and probably pitch pine in the Eastern States from southern Maine and Ohio to the Carolinas. *S. ocellinata* (Guenée) occurs in southern Ontario and the Northeastern and Lake States and feeds on honeylocust and black locust. Full-grown larvae are light yellow-green to green except for faint, wavy red lines and are about 25 mm long. *S. bisignata* (Walker) occurs in southern Canada and the Northeastern States and feeds principally on eastern white pine. *S. sexmaculata* (Packard), the **green larch looper**, a widely distributed species, feeds on larch. These species of *Semiothisa* overwinter as pupae in the duff. Eggs are laid singly on host foliage throughout the growing season *(782)*.

Eufidonia notataria (Walker) occurs on eastern white pine in the Atlantic Coast States. In southern Canada, it has been observed mainly on tamarack, eastern hemlock, balsam fir, and spruce. Full-grown larvae are dark green and about 25 mm long. They have a light-colored line on the dorsum, two stripes along each side, and fine brown markings in herringbone pattern on lobes. Larvae are present from July to September, and winter is spent in the pupal stage. The russet-brown eggs are laid singly or in clusters in leaf axils and at forks of branches of recent growth *(783)*.

Melanolophia canadaria (Guenée) feeds on the foliage of various deciduous plants such as basswood, birch, ash, willow, larch, and a few shrubs in the United States and Canada. Full-grown larvae are 20 to 25 mm long. The body is yellow-green and has a broken, purplish line on the top and yellowish stripes suffused with purplish red on each side. Larvae are present from June to early August, and they overwinter in the ground.

Anacamptodes ephyraria (Walker) has been observed feeding on hemlock in the Northeastern States and on several hardwoods in Canada and Northeastern States south to Texas and Florida *(783)*. Full-grown larvae are greenish or light gray to reddish-brown with a brown herringbone pattern on lobes, and are about 25 mm long. The head is bilobed and wider than the thorax, and the second abdominal segment is usually swollen at the sides. Winter is spent as a pupa. *A. pergracilis* (Hulst) feeds on baldcypress in the South (fig. 76). During a 1980–81 outbreak in Florida, trees on 24,000 hectares were defoliated. This species may have as many as six generations a year. In winter, when normal baldcypress is leafless, larvae feed on previously defoliated trees which have reflushed. The overwintering form is unknown. Light-green eggs are deposited under the bark of the stem primarily in the upper branches. Pupation occurs under bark or in epiphytic bromeliads (fig.

77). A larval parasite, *Ichneumon navus* Say, appears to be the major natural controlling agent for this looper *(338)*.

Iridopsis larvaria (Guenée) feeds on aspen, paper birch, alder, and other deciduous plants in the Northeastern States and southern Canada. Full-grown larvae are yellowish green to light brown and 20 to 25 mm long. There is a reddish band on the second abdominal segment, several reddish diamond-shaped formations on the dorsum, and a pair of blunt tubercles on the eighth abdominal segment *(783)*.

F-532013

Figure 76.—Adult female moth of *Anacamptodes pergracilis*. Note extended ovipositor, which is used to insert eggs in bark of baldcypress.

F-532014

Figure 77.—*Anacamptodes pergracilis* pupae in cells in bark of baldcypress.

Ectropis crepuscularia (Denis & Schiffermüller), the **saddleback looper**, feeds on the foliage of a wide variety of trees, especially conifers, from coast to coast in southern Canada. South of Canada, it is usually found on hardwoods such as birch, maple, oak, poplar, and walnut. Full-grown larvae are reddish to chocolate brown and 25 to 30 mm long. The head is somewhat mottled, and there is a pair of blunt tubercles on the eighth abdominal segment. Larvae are present from May to September in the Northeastern States and the winter is spent in the pupal stage in the ground.

Epimecis hortaria (F.) occurs on sassafras and yellow-poplar in the Atlantic Coast States. The adult is either dark colored to almost black or light gray with a dusting of brown. The forewings are marked with lines and the wingspread is about

50 mm. Full-grown larvae are yellowish to dark brown with five pale, yellowish longitudinal lines and are about 30 mm long. Larvae are present during June and July, and they feed at night. There is one, and possibly a second, generation per year.

Phigalia titea (Cramer) occurs in southern Canada westward to Saskatchewan and the Eastern States. Its hosts include various hardwoods, especially northern red oak, red and sugar maples, basswood, hickory, and elm. Numerous outbreaks have been recorded in mixed oak and maple stands in the Northeastern States and Virginia. The male moth has a wingspread of 37 mm. The thorax is whitish, and the abdomen is marked with two rows of black dots on the dorsum. The forewings are dotted with dark-brown specks and are marked with three blackish lines and a row of black spots along the outer margin. The wings of the female are vestigial and functionless. Full-grown larvae are pinkish with many blackish longitudinal lines and are about 37 mm long. The thoracic segments are thick, and there are hairy tubercles on all body segments. Pinkish-red eggs are laid in crevices in the bark of dead branches. Larvae are present from May to July, and winter is spent in the pupal stage beneath litter *(1187)*.

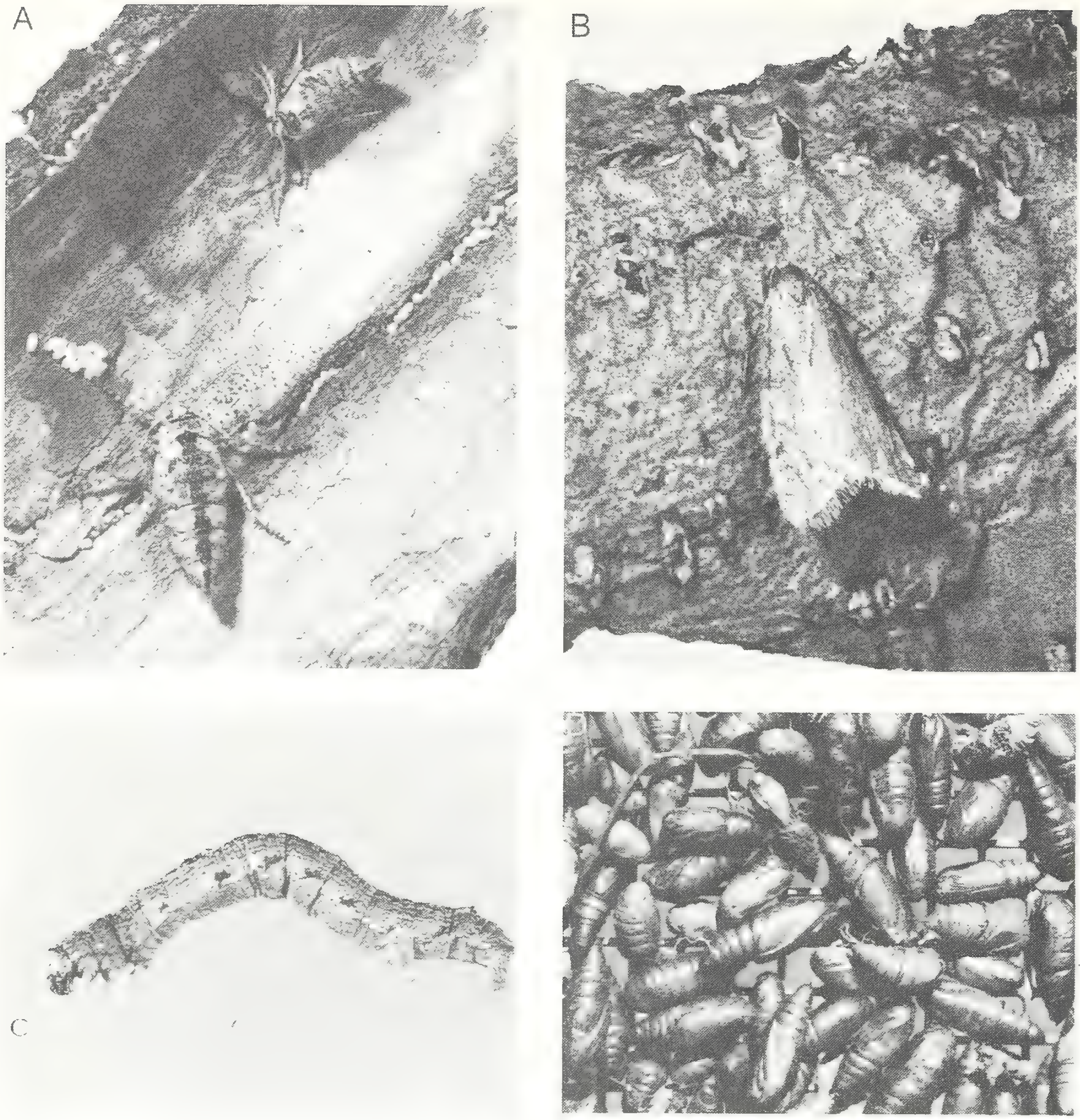
The **spring cankerworm**, *Paleacrita vernata* (Peck) (fig. 78), occurs throughout the same general range as the fall cankerworm, also farther southwest and west to Texas, Colorado, and California. Its hosts are about the same as those of the fall cankerworm. Apple and elm are especially favored. Male moths have a wingspread of about 21 to 30 mm. The forewings are silky with loosely attached, brownish scales, and are crossed by three jagged, dark lines. The hindwings are pale, ashy gray, and each bears a dusky discal spot. Each of the first seven joints of the abdomen bears two transverse dorsal rows of stiff, reddish spines, pointed posteriorly. Female moths are wingless and generally whitish or brown or black. There is a darker stripe down the back and two transverse rows of reddish spines on each of the first seven joints of the abdomen. These spines are often so prominent as to give the dorsum a reddish aspect.

Full-grown larvae are reddish to yellowish brown, yellowish green, or blackish and are about 18 to 30 mm long. The head is light and mottled with brown. The body is usually marked with a yellow stripe just below the spiracles, and a broad greenish-yellow stripe down the middle of the venter. There are two pairs of prolegs, one on each of the eighth and anal segments.

Spring cankerworms do not spin cocoons, but spend most of the winter as larvae in earthen cells. Pupation occurs in late winter, and the adults appear in early spring about the time frost leaves the ground. Female moths crawl up the trunks of trees, mate, and deposit loose clusters of 100 or more eggs in bark crevices or under bark scales on the trunk or branches. Hatching occurs by early May and the larvae become full grown by early June, at which time they drop and enter the soil. Like the fall cankerworm, this species may be an important pest of shade trees and forested areas.

Fall and spring cankerworm populations are normally kept under control by natural control factors. Outbreaks often occur, however, over large areas. Isolated trees can be protected by placing sticky bands around the trunks to prevent female moths from climbing to lay their eggs *(1224)*.

The **linden looper**, *Erannis tiliaria* (Harris), occurs from Nova Scotia to central Alberta and south to Missouri, Kansas, and Utah *(783)*. The larvae feed on the foliage of a wide variety of hardwoods, especially basswood, elm, hickory, maple, oak, birch, and apple. The female adult is light gray to brownish, wingless, about

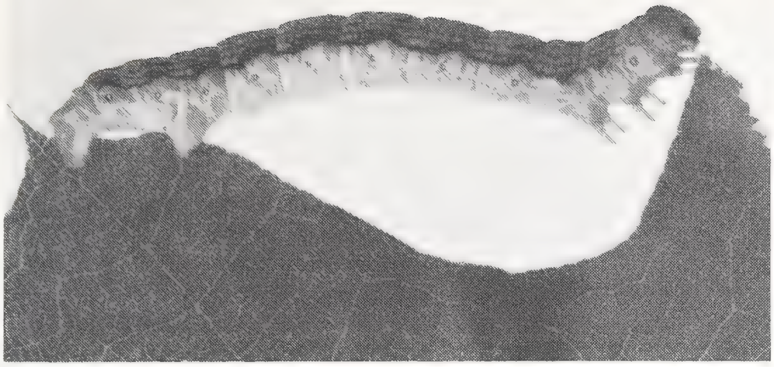


A,B,D, F-531247
C, courtesy Can. For. Serv., Can. Dep. Environ., Sault Ste. Marie, Ont.

Figure 78.—Spring cankerworm, *Paleacrita vernata*: A, females and eggs; B, male; C, fully grown larva; D, pupae.

12 mm long, and is marked with black spots on the sides and back. Male moths have fully developed wings with a wingspread of about 42 mm. The forewings are buff and marked with two transverse, wavy brown bands and a sprinkling of brownish dots. Full-grown larvae (fig. 79) may be bright yellow, with rusty-brown heads, and 10 dark wavy lines running down the dorsum, or they may be entirely light yellow. They are about 37 mm long.

Winter is spent in the egg stage and hatching occurs in April or May. Larvae are present until July, then pupate in cells in the ground. Adults are present from October to December. The females crawl up the trunks of trees and deposit their eggs singly or in small groups in bark crevices. There is one generation per year. Several outbreaks have been recorded in the Northeastern States and Canada. At such times, male moths are attracted to street lights in nearby towns in considerable numbers. Two dipterous parasites, *Pseudotachinomyia slossonae* (Townsend) and *Phryxe vulgaris* Fallén, commonly attack the larvae. A virus epizootic occurred in an outbreak in Quebec in 1961.



Courtesy Can. For. Serv., Can. Dep. Environ., Sault Ste. Marie, Ont.

Figure 79.—Larva of the linden looper, *Erannis tiliaria*.

Larvae of *Lycia ursaria* (Walker), the **stout looper**, feed on the foliage of a number of hardwoods such as paper birch, willow, elm, maple, poplar, basswood, ash, pin cherry, and alder in eastern Canada and the Atlantic Coast States. Willow and paper birch appear to be preferred. The adult is gray, stout-bodied, and has a wingspread of about 45 mm. Both pairs of wings are crossed by diffused, blackish lines. Full-grown larvae are about 35 mm long. There are four large whitish spots on the front of the prothorax, and the gray body is marked with numerous longitudinal, wavy red-brown lines and creamy-white spots. Larvae are present from May to July, and winter is spent as pupae in the ground. This species is occasionally quite common in New England.

Nacophora quernaria (J. E. Smith), the **oak beauty**, occurs on oaks in the Atlantic Coast States and Pennsylvania, and on paper birch from New Brunswick west to central Saskatchewan in Canada. Full-grown larvae are about 50 mm long. The head is bilobed and angular; the body slate gray, stoutish, and armed with brownish tubercles. The tops of the first two thoracic segments are also marked with reddish brown and black. Larvae are found from June to September; winter is spent in the pupal stage. The yellowish-green egg is iridescent and acorn-shaped with a circle of white spots on the top *(434)*.

Plagodis serinaria Herrich-Schäffer feeds on various hardwoods such as red and sugar maples, yellow and paper birches, beech, and aspen in the Northeastern States and eastern Canada. Full-grown larvae are about 37 mm long. The head is bilobed and angular; the body, dull brown with blotches of lighter and darker shades and a prominent swollen area on the back of the sixth abdominal segment. Winter is spent in the pupal stage, and adults are present during May and June. *P. kuetzingi* (Grote) feeds on ash in the Northeastern States, Nova Scotia west to Ontario and the Lake States *(434)*.

Probole amicaria (Herrich-Schäffer) and *P. alienaria* Herrich-Schäffer feed on various hardwoods throughout much of the Eastern United States and from coast to coast in southern Canada. Full-grown larvae are green to brownish and about 30 mm long. The head is rather small and flattened in front, and there are two whitish spots on the tops of all body segments except the prothorax. Larvae are present from July to early September, and winter is spent in the pupal stage.

The **filament bearer**, *Nematocampa limbata* (Haworth), feeds on the foliage of hemlock, fir, and such hardwoods as maple, oak, gray birch, pin cherry, buckeye,

and apple in the Eastern United States and eastern Canada. Full-grown larvae are greenish brown with reddish-brown heads and are about 18 mm long. There is a pair of tubercles on the first abdominal segment; a pair of long, slender, brownish filaments on each side of the second and third segments; a pair of small, rusty-red tubercles on the eighth segment; and a broad stripe that extends from the dorsum of the prothorax to the first pair of filaments. Larvae are active from May to July; adults, from late June to August.

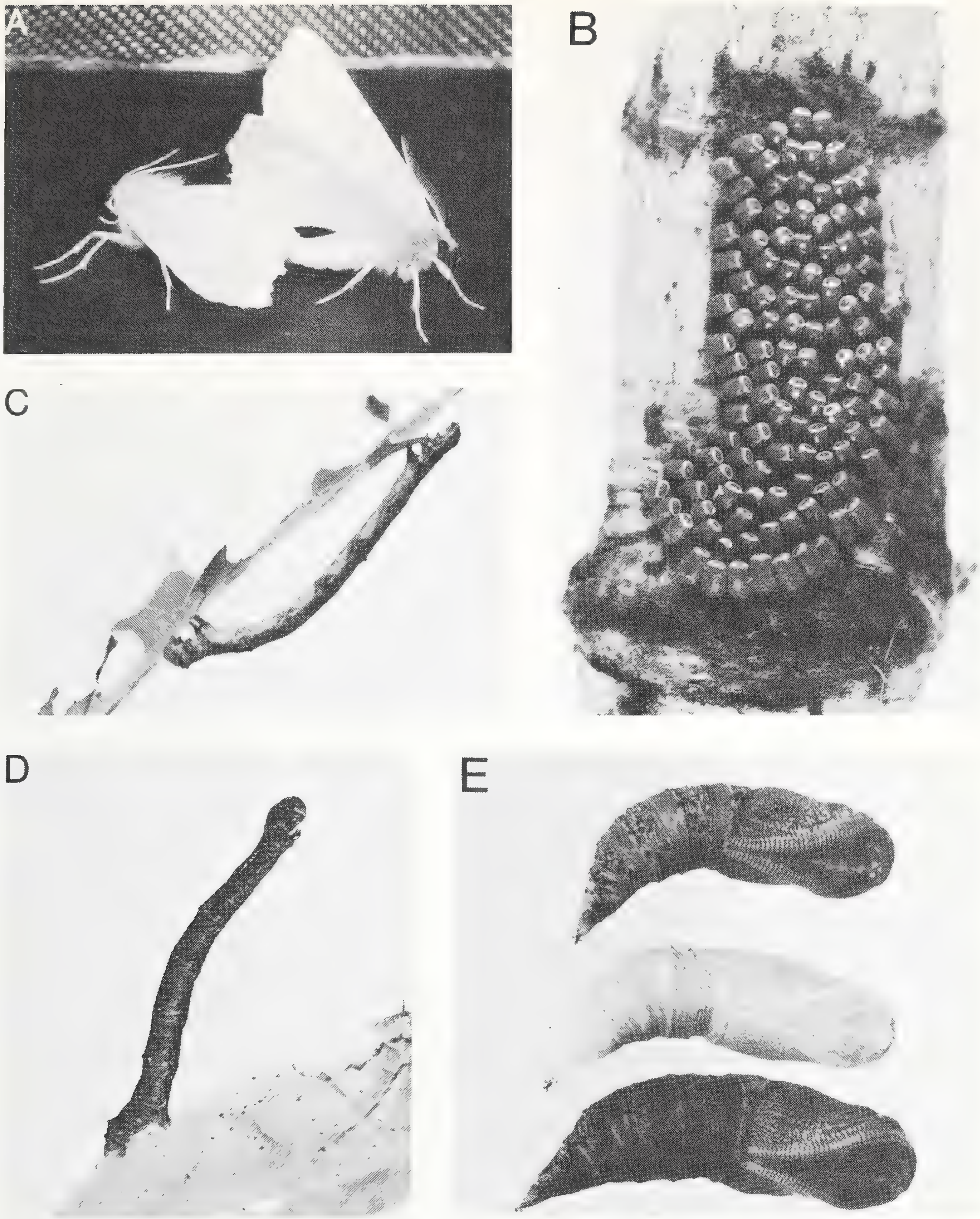
The **elm spanworm**, *Ennomos subsignarius* (Hübner) (fig. 80), occurs in southern Ontario and throughout the Eastern United States, west to Wisconsin, Colorado, and Texas. Its preferred hosts are hickory, oak, red maple, and ash but it attacks a large number of other hardwoods *(208)*. About 100 years ago, it was best known as a shade tree pest in the larger cities of the Eastern United States *(561)*. It also has been a predominant forest pest with widespread severe outbreaks occurring in the southern Appalachians and Connecticut *(395, 653)*.

The adult is a powdery white moth with a wingspread of 30 to 37 mm. Larval color is related to population density *(334)*. Full-grown larvae in outbreak areas are usually dull, slate black except for rusty head capsules; a small proportion of the larvae may be light green with yellow head capsules. When populations are low, there is a higher proportion of the lighter colored larvae. They are about 50 mm long.

Winter is spent in the egg stage. Hatching begins in late April in the South. Farther north, it may not start until late May or early June. Young larvae feed on the lower surfaces of leaves and produce a typical shothole effect. Older ones eat the entire leaf with the exception of the midrib and petiole. To pupate, mature larvae spin coarse, netlike cocoons of silken threads, often on partly eaten leaves. In completely defoliated stands, cocoons may be spun on exposed branch tips, in leaf axils, in bark crevices, or stumps of undergrowth.

The elm spanworm is capable of completely defoliating large areas of mixed hardwood forests during outbreaks. Between outbreaks, populations often exist at very low levels. A number of insect parasites and predators were found in fairly large numbers during the latter stages of some of the outbreaks and probably helped in bringing them to an end. The hymenopteran *Telenomus droozi* Muesebeck parasitized and destroyed over 80 percent of the eggs in certain areas *(209, 336, 337, 895)*. In Connecticut, *Ooencyrtus ennomophagus* Yoshimoto, a parthenogenetic egg parasite with more than one generation per year, ended an outbreak in about 2 years *(654)*. The predacious beetle *Calosoma scrutator* (F.), a voracious feeder on lepidopterous larvae, was also abundant in outbreak areas.

Ennomos magnarius Guenée, the **notched-wing geometer**, is widely distributed in southern Canada and the Northern States. It feeds on many species of hardwoods such as white ash, basswood, maple, quaking aspen, paper birch, beech, willow, and elm. The adult is yellowish and has a wingspread of about 60 mm. The forewing has a reddish tinge, is thickly flecked with brown dots, has a conspicuous lobe near the middle, and is shaded with brown on the outer margin. Mature larvae are about 50 mm long and yellowish green to dark brown or twiglike. Reddish areas occur on the tops of segments two and five and on the venter of segment three. Adults deposit oblong eggs in long, single strings during August and September, and winter is spent in the egg stage. Hatching begins in May, and larvae are present from May to July or August. This species is sometimes fairly abundant but is seldom of economic importance.



A,B,C,D, F-531248
E, F-500619

Figure 80.—Elm spanworm, *Ennomos subsignarius*: A, adults mating (male distinguished by feathery antennae); B, eggs; C, light-colored larva; D, dark-colored larva; E, pupae (light larvae and pupae develop in low-density populations, darker from dense populations).

Pero honestaria (Walker) occurs on black locust, pin cherry, and larch in the Eastern States. Full-grown larvae are about 37 mm long and dark brown, with paler, longitudinal markings. The head is bilobed and the body increases in girth toward the rear. There appears to be two generations per year. *P. morrisonaria* (Henry Edwards) occurs on a wide variety of trees, including fir, spruce, larch, pine, willow, and aspen. The species is single-brooded and occurs from Nova Scotia south to Virginia and west to the Pacific Coast *(434)*.

The **pine conelet looper**, *Nepytia semiclusaria* (Walker), attacks loblolly, sand, shortleaf, and slash pines from southeastern Virginia south and west to eastern Texas. The mature larva is from 25 to 50 mm long. It is vividly marked with a broad, brick-red dorsal stripe flanked by paired bright-yellow lateral stripes separated by a series of fine black and white lines. Head, thoracic legs, and prolegs are bright orange. The adult is grayish tan with a wingspread of from 25 to 30 mm. Each front wing is crossed by a pair of brown scalloped lines while a single similar line occurs on each hindwing. This species overwinters as an egg in masses under bark scales. Hatching occurs early in the growing season and the young larvae feed on the female flowers and conelets of slash, loblolly, and shortleaf pines and possibly also sand pine. In sand pine, old-growth foliage is the principal food *(359)*. Pupae are found among the needles. *N. pellucidaria* (Packard) occurs on fir, larch, pine, spruce, and hemlock in the Northeastern States.

The **false hemlock looper**, *N. canosaria* (Walker), occurs on hemlock, fir, white and black spruces, northern white-cedar, and larch in the Northeastern States and southern Canada, often in conjunction with hemlock looper *(1036)*. Full-grown larvae are about 25 mm long. The head is whitish or reddish brown and bears a few black dots; the body is whitish to green with tinges of yellow or red, black dotted, and has a yellowish stripe on each side below which are four or five dark, wavy lines. Larvae are present from June to August. The ellipsoidal eggs are truncated at one end and laid on bark in small clusters *(434)*.

The **hemlock looper**, *Lambdina fiscellaria* (Guenée), occurs from Newfoundland to Alberta in Canada and south to Georgia in the Eastern States. Its preferred hosts are balsam fir, white spruce, and hemlock. It also feeds on many other species during outbreaks such as larch, red and black spruces, jack pine, basswood, maple, paper and yellow birches, elm, and cherry. In the more southerly portions of its range, infestations develop mainly on hemlock. Outbreaks were recorded in Ohio, Wisconsin, Michigan, New York, and Maine during the 1920's and in Massachusetts, New Hampshire, and Vermont from 1949 to 1952. However, severe, prolonged outbreaks have been recorded only in eastern Canada *(1036)*. The adult is creamy tan to grayish brown with a tinge of purple and has a wingspread of about 62 mm. Two irregular purplish-brown lines cross the forewings, and a dot of the same color lies between them near the costal margin. Full-grown larvae are usually grayish green to grayish and are about 30 mm long. The head and body are marked with distinct black dots.

Adults are present from around mid-August to early October and deposit their eggs singly or in small groups on moss, lichens, or bark on limbs and trunks. Winter is spent in the egg stage and hatching occurs in June. Young larvae feed on opening buds or on old needles. Needles are often chewed off at the base and drop; others that are partially chewed off, usually dry out, turn brown, then drop. Pupation takes place in bark crevices, or in masses of lichens on or near the bark *(198)*.

Hemlock looper outbreaks may develop very suddenly, the most serious ones occurring in mature and overmature hemlock and balsam fir stands.

The **eastern pine looper**, *L. pellucidaria* (Grote & Robinson), occurs in several Atlantic Coast States and feeds on pitch, red, shortleaf, loblolly, pond, and possibly other pines. Several widespread outbreaks have been recorded during the past 70-odd years. The adult is ash gray to smoky in color and has a wingspread of about 37 mm. The forewing is crossed by two irregular diffuse dusky lines and bears a slightly sinuate discal dot. The hindwing is also crossed by a dusky line. Full-grown

larvae are pale straw to yellow with black markings and are 27 to 37 mm long. The body bears faint rows of blackish dots and short wavy lines on the top and sides, and the head is densely marked with light and dark spots.

Adults emerge in May and June and lay their eggs on the needles. The larvae feed on the needles until late September. Winter is spent in the pupal stage in the duff beneath the trees.

Lambdina fervidaria athasaria (Walker) occurs on hemlock, maple, oak, and beech in several Eastern States. Local outbreaks have occurred in Massachusetts, Connecticut, and Ohio. The adult resembles that of *L. pellucidaria* except for a slightly shorter wingspread. Full-grown larvae are yellowish and about 30 mm long. The head is marked with irregular brown to blackish spots. The top of the body is lighter than the sides. The sides are marked with wavy lines of dark or reddish brown, interrupted with dashes of white. Winter is spent in the pupal stage on the ground, just beneath the top crust of the leaf mold. Larvae are present from July to late September.

The **chainspotted geometer**, *Cingilia catenaria* (Drury), occurs in eastern Canada and the Northeastern States. It has many hosts including gray and paper birches, oak, poplar, willow, cherry, balsam fir, larch, and white spruce. Young eastern white and red pines growing in mixture with the above hosts are also subject to heavy defoliation. Blueberries, huckleberries, and small trees growing in pastures and cutover areas are especially subject to infestation. Local outbreaks have been recorded frequently in the Northeastern States.

The adult has a wingspread of 30 to 42 mm. The head and part of the thorax are orange-yellow; the body, white with black markings. The wings are smoky white and black spotted. Full-grown larvae are straw colored and about 50 mm long. The head and body are dotted with black spots, those on the sides of the body produce chainlike effects. There also are three or four thin, black lines below these rows of dots *(1037)*. Winter is spent in the egg stage. Larvae are present from June to August.

Tetracis cachexiata Guenée occurs on cherry in the Northeastern States. Full-grown larvae are about 37 mm long. The head is grayish, flattened, and square in front; the body, reddish brown to black with white markings and a black line running down the middle of the back after the fifth segment. Tubercles are also prominent. Larvae are present from July to September, and winter is spent in the pupal stage.

Eutrapela clemataria (J. E. Smith), the **purplish-brown looper**, is multivoltine and occurs on basswood, maple, quaking aspen, paper birch, pin cherry, sweetgum, and hemlock in eastern Canada and the Eastern United States, westward to the Mississippi River Valley. Full-grown larvae are purplish brown and up to 60 mm long. The head is rounded and bilobed, the second and fourth abdominal segments are swollen on top, and there are prominent tubercles on the fifth and ninth abdominal segments. Larvae feed from June to August in the North, and from April to October in the South. Winter is spent as pupae in cocoons in leaves on the ground. The truncate eggs are laid erect in large masses, much like those of *Alsophila (434)*.

Prochoerodes transversata (Drury), the **large maple spanworm**, occurs on various hardwoods such as maple, oak, willow, quaking aspen, paper birch, and mulberry in southern Canada and the Eastern United States. Full-grown larvae are light to purplish brown and about 50 mm long. The head is rounded and flattened in front, the second thoracic segment is swollen and streaked with red, and the eighth

abdominal segment bears a pair of prominent tubercles. Larvae feed from June to October, winter is spent in the pupal stage, and there are two generations per year.

The **pepper-and-salt moth**, *Biston betularia cognataria* (Guenée), occurs in eastern Canada and the Northeastern States where it feeds on elm, willow, poplar, black locust, cherry, and apple. The adult is dark brown to black and has a wingspread of about 55 mm. The light-gray forewings are suffused with gray-brown and have dark-brown to black crosslines *(783)*. Full-grown larvae, commonly called **cleft-headed spanworms**, are 50 to 75 mm long. The head is deeply cleft, granulated, and flat in front; there are tubercles on each side of the prothorax and on the fifth and eighth abdominal segments *(1037)*. Larvae feed from July to October, and winter is spent in the pupal stage in the litter.

Campaea perlata (Guenée), the **fringed looper**, is a common species in the Northeastern United States and Canada, and the larvae feed on balsam fir, hemlock, and many species of deciduous trees. Adults have whitish wings; the forewings are pointed at the apex and have two gray crosslines; the hindwings are scalloped on the outer margin *(784)*. The full-grown larva is 20 to 25 mm long and light brown to grayish with dark-brown markings *(784, 1036)*. *Protoboarmia porcelaria indicataria* (Walker) is also a common species in northeastern forests. Adults are gray. Larvae feed on a wide variety of trees including balsam fir, white spruce, larch, jack pine, birch, quaking aspen, and willow.

Family Mimallonidae
Mimallonid Moths

Adults of this family are stout-bodied moths with pectinate antennae. The forewings are falcate, bent at the middle, and heavy-veined. The humeral angle of the hindwing is much enlarged, and the frenulum is rudimentary. Two species are known to occur in the Eastern United States, neither of which is of economic importance. However, they both often attract attention.

Cicinnus melsheimeri (Harris), **Melsheimer's sackbearer**, is fairly common on oak, especially bur oak, from New England to the Lake States and southward. The adult is reddish gray and has a wingspread of 37 to 50 mm. The body is sprinkled with minute black dots; each wing is crossed by a narrow blackish band and marked by a black discal spot or bar. A newly hatched larva makes a shelter for itself by drawing two leaves together with strands of silk. Eventually, the larva constructs an ellipsoidal portable case from pieces of leaves and silk, leaving a circular hole at each end. It lives in the case but can leave it at will. To move the case, it bites off the strand of silk that anchors it and transports it to the new location. When it is at rest, the larva anchors the case with silk and plugs the openings of the case with its head and rear end. Winter is spent in the pupal stage, and adults appear during May and June.

Lacosoma chiridota Grote feeds on oak throughout much the same range as Melsheimer's sackbearer. Adults are dark yellowish brown, with deeply scalloped forewings, and have wingspreads of 25 to 30 mm.

Family Apatelodidae
Apatelodids

This family is represented in North America by only five species, two of which are encountered fairly often in eastern forests *(442)*.

Apatelodes torrefacta (J. E. Smith) occurs throughout the eastern part of the United States and feeds on maple, black cherry, and various other trees and shrubs. Full-grown larvae have rounded yellowish heads and are about 50 mm long. The body is whitish to yellow on the dorsum, except for a row or line of more or less

connected black spots. It has a row of black spots on each side, is blackish beneath, and is densely clothed with long, fine, white or yellow hairs. Long pencils of hairs, pale at the base and black at the tip, arise from the second and third thoracic and eighth abdominal segments. Larvae are present from June to September, and winter is spent in the pupal stage on the ground.

Olcerlostera angelica (Grote) larvae feed on the leaves of ash and lilac from New England and southern Canada to Florida and westward into the Ohio River Valley. Full-grown larvae are 50 to 62 mm long. The head is rounded, brown, and mottled with light and dark shades. The body is gray and covered with a network of fine wavy black lines, except for the top of the thorax that bears two broad black transverse bands. The tops of segments one and seven bear yellowish-green spots, long brown and white hairs project forward over the head from the prothorax, and whitish hairs project forward from the middle of the second and third thoracic segments. Most of the rest of the body is sparsely clothed with short white and black hairs. Larvae are found in August and September. Winter is spent in the pupal stage on the ground.

Family Lasiocampidae
Tent Caterpillar Moths and Allies

The family Lasiocampidae is represented in North America by about 37 species, several of which are important economic pests of trees *(442)*. The moths are medium-size and stout-bodied; the body, legs, and eyes are hairy; and the antennae are somewhat feathery. The larvae vary in form from nearly cylindrical to very much flattened; they are very hairy.

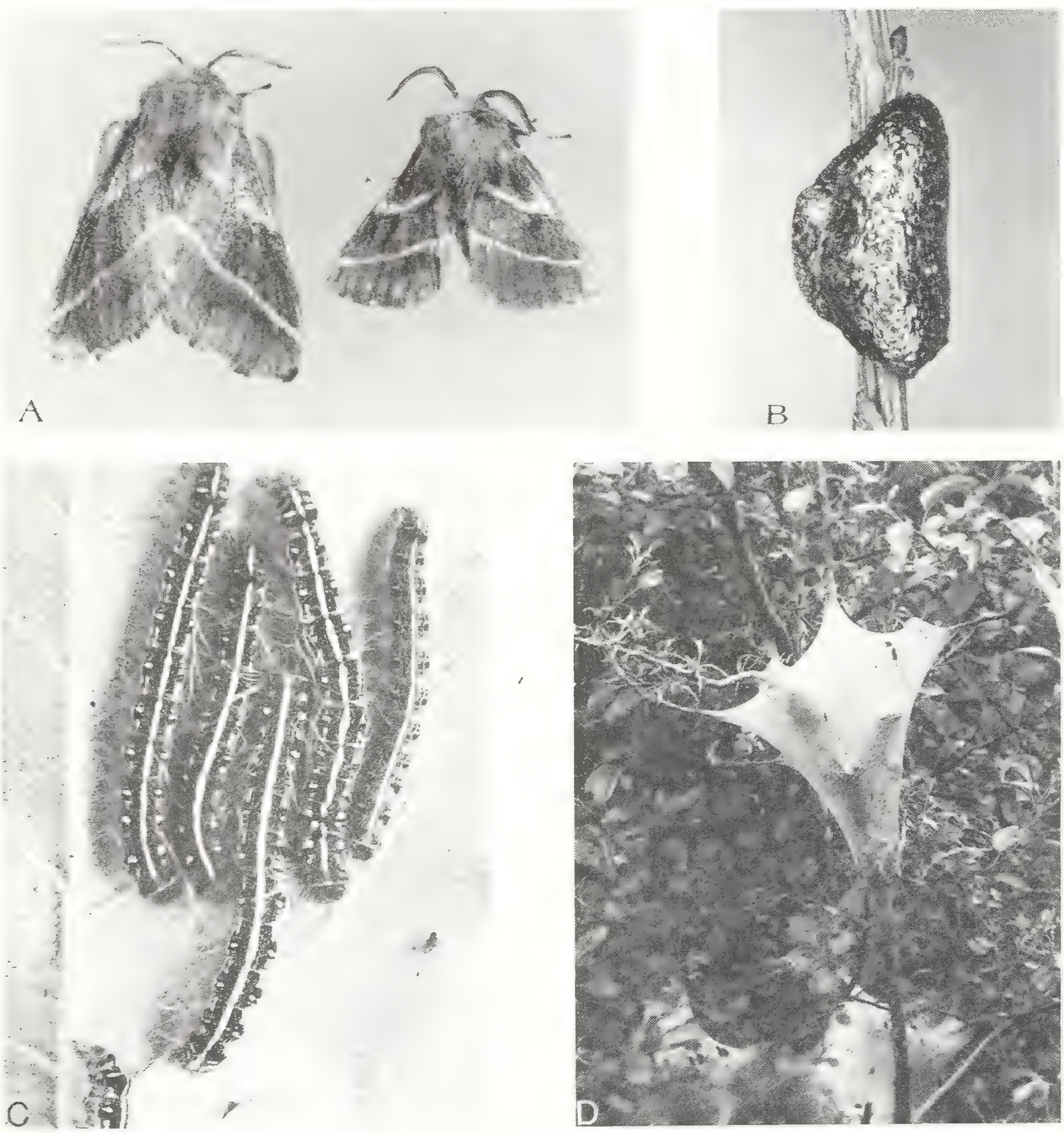
The majority of important species belong to the genus *Malacosoma*, and are commonly known as **tent caterpillars**. Four and a possible fifth species occur in the Eastern United States and eastern Canada. The remaining 11 North American species have a western distribution. A revision of the genus is available *(1149)*. This includes keys to the adults, mature larvae, and egg masses of all species and a discussion of their distribution, their hosts, and some of their habits, and parasites recovered. A complete listing of the various species is also available *(1344)*.

Eggs of tent caterpillar moths are laid either in flattened masses on the bark of limbs or trunks of trees or in masses that may encircle small twigs. The number of eggs per mass ranges from 100 to 400, usually from 150 to 250. As the eggs are deposited, they are held in place by a frothy substance called spumaline *(579)*. The majority of species cover their eggs with this material. Hatching occurs in the spring, about the time the new leaves of the host tree appear. Young larvae feed first on egg shells, then on the buds and young leaves. Those of tent-building species also immediately begin to construct a tent on a branch or in a nearby tree crotch. They do not feed from within the tent but on the leaves of neighboring branches. As they crawl to these branches, they spin strands of silk that they usually follow in returning to the tent, where they remain during periods between feedings. Species that do not construct tents assemble in clusters on branches and trunks during periods between feedings. Toward the end of an instar they spin nests of silk on branches and trunks on which they congregate to molt.

The larvae usually pass through five or six instars. By the time the last instar is reached, they are no longer gregarious, and they travel extensively in search of food. At this time, they are not very selective in their food requirements and will feed on a wide variety of hosts. When their food supply becomes scarce, they may migrate in search of other food, often for considerable distances. When they reach maturity, they spin cocoons in which to pupate. The cocoons are about 25 mm long,

fairly loosely constructed, and white or yellow because of a powdery material dispersed between strands of silk. Cocoons may be found within the old tents, inside logs, beneath loose bark, and between folded leaves.

The **eastern tent caterpillar**, *M. americanum* (F.) (fig. 81), is generally distributed throughout the eastern half of the United States and southern Canada. Its preferred hosts are cherry and apple, but it also attacks a wide variety of other forest, shade, and fruit trees. The adults are light to dark chocolate brown, the wings are lightly dusted with white scales, and the wingspread varies from about 37 to 50 mm. Each forewing is crossed by two oblique white or yellowish-white lines. The hindwing is uniformly chocolate brown and crossed by a faint white area. Full-grown larvae have black heads, sparsely clothed with long, fine, light-brown hairs, and are marked with an apparently continuous middorsal light stripe, bordered on each side with longitudinal reddish-brown and black wavy lines. The subdorsal area is marked with a central black area on each segment, crossed by a vertical blue mark posteriorly.



A, courtesy Can. For. Serv., Can. Dep. Environ., Sault Ste. Marie, Ont.
B, F-532847
C, D, courtesy Conn. Agric. Exp. Stn.

Figure 81.—Eastern tent caterpillar, *Malacosoma americanum*: A, adult male and female; B, egg masses encircling twig; C, larvae; D, a typical tent.

Winter is spent in the egg stage, and hatching occurs about the time the buds of the host tree begin to unfold in the spring. In Florida, adults may appear and lay their eggs even before hatching occurs in the northern parts of the insect's range. The larvae are gregarious. As soon as they hatch, they begin the construction of a tent in a nearby trunk or branch crotch, and continue to enlarge the tent as they grow. From this tent, the larvae crawl out to the foliage to feed. After feeding, they return to the tent to rest. When they become full grown, they leave the nest and wander in search of places to pupate. Pupation occurs in tough silken cocoons, dusted with a yellowish powder, on the bark of trees, on fences, on brush and weeds, among dead leaves and other debris on the ground, and even on the sides of buildings. When the adults appear, they lay eggs in essentially a clasping mass on small twigs or branches, or on the trunks of small trees. In the Lake States, eggs are often found on the trunks of very small trees about 15 cm above the ground. There is one generation per year *(156, 302)*.

Most of the hosts of the eastern tent caterpillar have little value, thus it usually does not cause economic losses. It may be of some importance, however, when it defoliates commercial-size black cherry whose wood is of value for furniture *(700)*. The species is primarily a nuisance pest. Infested trees in parks, recreational areas, along roadsides, and in the vicinity of homes may be disfigured.

During most years, the eastern tent caterpillar is controlled satisfactorily by its natural enemies. Egg parasites may account for one-quarter of the exposed eggs, but only 1 percent of the spumaline-covered eggs *(276)*. Periodically, however, populations reach outbreak proportions. An effective method of control on isolated trees is to prune off and burn twigs containing egg masses. Destroying larval tents, preferably when the tents are still small, is also effective. *Bacillus thuringiensis* and a number of chemical insecticides are effective in controlling the larvae.

Malacosoma californicum lutescens (Neumoegen & Dyar), the **prairie tent caterpillar**, occurs throughout the Great Plains area east of the Rocky Mountains to central Texas. Its hosts are recorded as common chokecherry, willow, American plum, and gooseberry. Male adults range from dark reddish-brown to very light yellow; females are yellowish to medium reddish-orange brown. The forewings are crossed by light yellowish lines, and the wingspread is about 37 to 50 mm. Full-grown larvae are about 50 mm long. The head is blue, mottled with black, and sparsely covered with fine whitish to orange setae. The middorsal area of each abdominal segment is marked with an elongate somewhat pointed, blue-white dash. These dashes combine to form a broken middorsal stripe.

Eggs are laid in flattish, clasping masses on twigs and branches and are covered with light-brown or grayish spumaline. The larvae construct relatively large tents that look like those of the eastern tent caterpillar. Defoliation is usually confined to branches, but during outbreaks trees may be completely defoliated. Because of the low value of its hosts, the species is of minor economic importance.

The **Sonoran tent caterpillar**, *M. tigris* (Dyar), occurs in the southern Great Plains, southern Rocky Mountains, the Southwest, and Mexico. So far, it is not known to occur farther eastward than central Texas. Its host plants are various oaks and possibly other species. Eggs are laid in encircling bands on very small twigs, occasionally dead twigs. The masses differ from those of other members of the genus in not being covered with spumaline. The larvae construct relatively small tents on which they congregate to molt. Tents are usually formed near the end of each instar. This species does not appear to be of much economic importance,

unless it occurs in association with other defoliating species. It has combined with the forest tent caterpillar in heavily defoliating oaks in south-central Texas.

The **western tent caterpillar**, *M. californicum* (Packard), occurs primarily in western America. However, spotted infestations also occur eastward across central Canada to Quebec. It has also been collected in New Hampshire, New York, and northwestern Minnesota *(1149)*. Alder, serviceberry, willow, common chokecherry, birch, apple, plum, cherry, and quaking aspen are known to be attacked. Full-grown larvae are predominantly black and yellow or yellow-orange. The head is mottled blue-black and sparsely covered with fine yellow-orange setae. The dorsum of the abdomen is marked by a stripe formed by a series of elongate bluish-white, somewhat pointed dashes, one per segment.

Eggs are laid in flat, clasping masses covered with brown or dark-brown spumaline. The tents are similar to those of the eastern tent caterpillar. The species is of little or no economic importance in eastern America. Larvae may be controlled with *Bacillus thuringiensis (863)*.

The **forest tent caterpillar**, *M. disstria* Hübner, occurs throughout most of the United States and Canada and feeds on a wide variety of hardwoods *(71)*. In the North and West, quaking aspen is preferred; in the South, water tupelo, blackgum, sweetgum, and various species of oak are most heavily defoliated. The adult is stout-bodied, light buff-brown, and has a wingspread of about 25 to 37 mm. The forewings have two darker oblique bands near the middle (fig. 82A). Full-grown larvae have light-blue heads mottled with black and sparsely covered with fine, whitish setae. Each abdominal segment is marked dorsally with a yellowish-buff, keyhole-shaped spot which may be divided to form an anterior spot and a smaller posterior spot (fig. 82B). The venter is blue-gray to dark gray, usually with a median spot on each segment, and often with a dark-gray area running the full length of the body between the bases of the legs.

Winter is spent as a complete embryo within the eggshell and hatching occurs in the spring, about the time the buds on the host tree begin to swell. Young larvae feed on expanding buds; older ones devour the foliage, often completely defoliating the tree. During the first four to five instars, the larvae are gregarious. At first, all of those from one egg mass cluster on one leaf or one group of small expanding leaves. Later, they become more widely dispersed on surrounding foliage. Although this species is referred to as a tent caterpillar, it does not construct tents. However, larvae do lay down strands of silk along which they travel. They also form silken mats on the trunks or branches on which they congregate in masses to rest or to molt (fig. 82C). As they approach maturity, they tend to wander individually over the trees and other vegetation in search of food or places to pupate. Pupation occurs in pale-yellow cocoons spun in folded leaves, in bark crevices, on shrubs or other vegetation, and occasionally on buildings. Adults appear from late May in the South to late June and July in the North. Eggs are laid in masses of 100 to 350 in bands 25 to 37 mm wide that encircle twigs up to 37 mm in diameter. The eggs are cemented together and are coated with dark-brown spumaline. There is one generation per year.

The forest tent caterpillar has been an important enemy of forest, orchard, and shade trees for many years. During the period from 1886 to 1962, several general outbreaks, some of which covered thousands of square kilometers and lasted for 2 to 6 years, occurred in the Northern United States and eastern and western Canada. Since the 1930's several outbreaks have also occurred in Virginia, South Carolina, Mississippi, and Louisiana *(577)*. Outbreaks occurred repeatedly in Alabama

A and B, Courtesy Conn. Agric. Exp. Stn.;
C, F-506692

Figure 82.—Forest tent caterpillar, *Malacosoma disstria*: A, adults; B, full-grown caterpillar, showing keyhole spots along the dorsum; C, caterpillars at rest on trunk and branches of an aspen.

during the 1960's, mostly defoliating water tupelo on a gross area of 17,000 hectares *(213, 1147)*. Damaging populations arose again in 1981, including Louisiana, North Carolina, Kentucky, and Alabama *(581)*. In general, tree mortality has not been severe, but losses in reduced growth following defoliation have been great. Studies in Minnesota indicate that there is about a 70 percent reduction in basal area growth of aspen during the first year of heavy defoliation. About 90 percent reduction also occurs during the second year of heavy defoliation, plus about 15 percent reduction during the year of recovery. Total reduction for the 3-year period averages about 58 percent *(349)*. Heavy defoliation of bottom-land gums in the South results in substantial mortality and dieback, as well as severe reduction in annual growth. In the Northeast, heavy defoliation in sugar maple orchards not only causes serious injury to the trees, but also a reduction in the quantity and quality of the sap. Outbreaks in recreational areas adversely affect business because of the nuisance created by migrating caterpillars and the midwinter appearance of defoliated trees during the tourist season. Discussions of the effects of defoliation on quaking aspen in Canada are published *(570, 1035)*. Outbreaks have been associated in eastern and central Canada with a cool winter and warm spring 2 to 4 years earlier *(628)*.

Outbreaks usually subside after 3 or 4 consecutive years of defoliation. Several adverse environmental factors are responsible for population declines. Mortality of pharate larvae, possibly caused by low winter or spring temperatures, may be quite high *(1279, 1346, 1347)*. Harsh weather conditions may cause death of large numbers of the early instars. Excessively high temperatures later in the spring may kill large numbers of adults and seriously reduce the viability of newly laid eggs. Mortality of the late instars may be severe or complete as a result of starvation in heavily or completely defoliated stands. A polyhedrosis virus disease sometimes kills enormous numbers of larvae in the late stages of outbreaks *(1145)*. The sarcophagid parasite, *Sarcophaga aldrichi* Parker, often becomes extremely abundant during the late stages of outbreaks in the Lake States and greatly aids in termination of outbreaks *(576)*. Other natural enemies include many species of insect parasites *(1345)*. *Bacillus thuringiensis* and various chemical insecticides may be used to control larvae *(527)*.

Tolype velleda (Stoll), the **velleda lappet moth**, occurs from southern Canada south through the Atlantic States to Florida and west to the Lake States. The larvae feed on the foliage of various hardwoods including ash, quaking aspen, basswood, cherry, elm, maple, holly, oak, and apple. The adult has a white head and thorax, a gray abdomen, and a large blackish spot in the middle of the dorsum. The wings are usually gray, sometimes dusky, are crossed by white lines, and have a wingspread of 37 to 62 mm. Full-grown larvae are gray with faint longitudinal lines and are about 62 mm long. The body is flattened and has lateral lappets, each of which has many long hairs, thus forming a fringe along each side of the body. There is a pair of warts, bordered posteriorly by a velvety black band, on the metathorax. Adults appear in September and October. Females lay their eggs in rows and cover them with hairs from the abdomen. Larvae are present from June to August. Pupation takes place in tough, flattened, parchmentlike cocoons on the bark. There is one generation per year. This species seldom causes serious injury. The related but smaller species, *T. laricis* (Fitch), feeds on larch. Its range and life cycle are similar to those of *T. velleda*.

The **lappet moth**, *Phyllodesma americana* (Harris), is generally distributed, but not often common, through the Eastern States and southern Canada. Its hosts are quaking aspen, cherry, hickory, birch, maple, oak, and various other hardwoods. Adults are reddish brown and have wingspreads of 30 to 50 mm. The inner angle of the forewing and the costal margin of the hindwing are deeply notched, and there is a pale band edged with irregular dark-brown lines beyond the middle of each. Full-grown larvae are bluish gray, somewhat mottled above, have lateral lappets, and are about 62 mm long. There are transverse scarlet bands on the second and third thoracic segments, in each of which are three black dots. Winter is spent in the pupal stage in a tough, flattened cocoon, usually on the bark of the tree. There is one generation per year in the North and a partial second one in the South.

Family Saturniidae
Giant Silkworm Moths

This family contains some of the largest and most colorful moths in the Eastern United States *(226, 403)*. The larvae, also large and conspicuous, are more or less armed with tubercles and spines. Because of their habit of spinning large, dense silken cocoons in which to pupate, they are known as giant silkworms. The larvae feed on a wide variety of trees and shrubs; however, because they usually occur singly and in low numbers, they are seldom injurious. Some of the most common species are discussed briefly below.

The **cynthia moth**, *Samia cynthia* (Drury), was introduced into this country from Asia more than 100 years ago and now occurs in urban areas from Massachusetts to Georgia and west to Indiana. Its preferred host is ailanthus, but cherry, plum, and other hosts are also infested. The adult is olive brown with rows of tufts of white hairs on the abdomen, and has a wingspread of 150 to 200 mm. Full-grown larvae are about 75 mm long and have yellowish-green heads and a whitish bloom dorsally on the body. The rest of the body is light bluish green to yellowish, spotted with black, and there are long, bluish tubercles with short bristles on each body segment. Moths are present from June to August; larvae from July to October. Winter is spent as pupae in pendulous cocoons on the tree or on the ground.

The **cecropia moth**, *Hyalophora cecropia* (L.), occurs throughout the Eastern United States and in southern Canada. The larvae feed on a wide variety of hardwoods such as apple, ash, birch, cherry, hawthorn, walnut, maple, sassafras, willow, elm, poplar, and basswood. Feeding damage can be severe in shelterbelt

plantings in the northern Great Plains. The moth has a wingspread of 125 to 150 mm. There is a white, crescent-shaped spot near the center of each wing, a red-bordered crossband on each wing, and a dark spot near the end of each forewing. They fly from April until June, depending on location. Full-grown larvae are 75 to 100 mm long. The head is green with two black spots on each side, and the body is pea green. There are pairs of large, coral-red tubercles dorsally on the second and third thoracic segments, 15 yellow tubercles on top of the first to eighth abdominal segments, and blue tubercles on each side. All tubercles bear stiff, black bristles. Winter is spent in large, thick, tough, gray-brown silken cocoons firmly fastened lengthwise to bare branches. Larvae may be found from June to October, depending on location. The tachinids *Lespesia samiae* (Webber) and *Winthemia cecropia* (Riley) are common parasites in the Northeast.

The **promethea moth**, *Callosamia promethea* (Drury), occurs throughout most of the Eastern United States and southern Canada, and feeds on a variety of hosts such as ash, cherry, lilac, sassafras, spicebush, yellow-poplar, maple, and birch. The adult has a wingspread of about 75 mm. The wings of the female are reddish purple to brown with light-brown borders, and are crossed near the middle with a wavy white line; each bears an angular white spot near the middle. Each forewing also bears an eyelike spot near the apex. A full-grown larva is about 50 to 62 mm long. The head is small and yellow; the body bluish or greenish white. The second and third thoracic segments each bear a pair of large, coral-red tubercles or horns; the eighth abdominal segment bears a large yellow one. Each segment is also ornamented by a series of black buttons. Winter is spent in a tough, light-colored cocoon enclosed in a leaf. The petiole of the leaf is attached to the twig by a very strong band of silken threads.

The **luna moth**, *Actias luna* (L.), occurs from southern Canada to Florida and Texas and has many hosts such as beech, birch, persimmon, sweetgum, willow, oak, hickory, black walnut, eastern hophornbeam, and butternut. The adult moth, a very beautiful insect, has delicate green wings that may spread to well over 100 mm. Each forewing bears a conspicuous eyelike spot and is edged with a purplish-brown band. The hindwings extend into long, curved swallowtails. The full-grown larva is about 75 mm long. The head is bluish green with brown on the sides; the body, pale green with six pinkish or greenish tubercles armed with bristles arising from each segment. A pale-yellow line runs along each side of the body. The tips of the dorsal tubercles on the second and third thoracic segments are red; the remainder, yellow. Winter is passed in a cocoon, usually on the ground. Moths are present from April to September, depending on location. There may be two or even three generations per year in the South.

The **polyphemus moth**, *Antheraea polyphemus* (Cramer), is widely distributed throughout the United States and Canada and feeds on many species of trees including basswood, beech, birch, elm, hawthorn, hickory, maple, oak, yellow-poplar, willow, ash, butternut, walnut, sassafras, and sycamore. The moth is yellowish brown and has a wingspread of 100 to 150 mm. There is an eyelike transparent spot and a sooty, transverse stripe outwardly edged with light pink near the outer margin of each wing. Full-grown larvae are apple green and about 75 mm long. The head is reddish brown, and the thoracic shield is sometimes margined with yellowish green along the front. Body segments are angular on the back, and each bears six orange or golden tubercles from each of which arise one to three bristles. The last segment bears a purplish-brown V-shaped design. Winter is spent in a tough, thick cocoon usually enclosed in a leaf attached to a twig or on the

ground. Larvae may be found from June to October. The tachinid *Lespesia sabroskyi* Beneway is a common parasite everywhere.

The **io moth**, *Automeris io* (F.), occurs throughout the Eastern United States and attacks a wide variety of trees including paper birch, cherry, black locust, quaking aspen, willow, beech, apple, maple, oak, hickory, elm, mulberry, dogwood, and sycamore. Female moths are purplish red and have a wingspread of about 75 mm; males are yellowish and slightly smaller. There is a large, circular, black eyespot with a tiny white center on the upper surface of each hindwing and a smaller but similar one on the lower surface of each forewing. Small larvae are gregarious. Full-grown larvae are about 65 mm long. The body is pale green with a broad, reddish-brown stripe on each side, margined with white and reddish lilac. Whorls of branched, black-tipped, green, poisonous spines rising from small conical tubercles on each body segment cause a severe nettling effect when they come into contact with the skin. Moths are present from May to September; larvae, from July to October, with two broods in the South. Winter is spent in the pupal stage in a thin, brown, oval cocoon, often covered with bits of dead leaves and other debris, and usually on the ground.

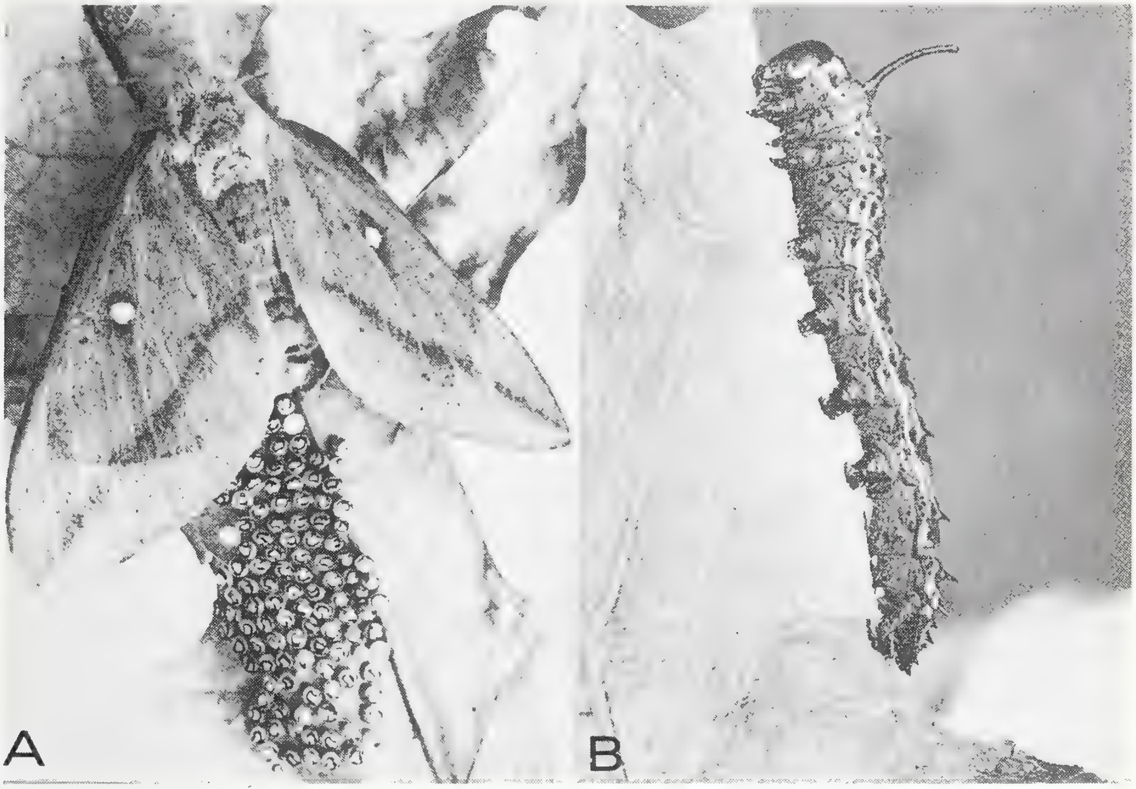
The **buck moth**, *Hemileuca maia* (Drury), occurs from Maine and Wisconsin to Florida, Louisiana, and Texas, and it apparently feeds exclusively on certain species of oak. Adults fly mostly in October, and have black, thin-scaled, sometimes semitransparent wings. A common white band crosses both the forewing and hindwing near the middle. Small larvae are gregarious. Full-grown larvae are about 62 mm long. The head is deep reddish-brown; the body, dull brownish to black and covered with small, yellowish dots. Each body segment has tufts of bristles or compound spines arising from tubercles. The spines cause a nettling effect when in contact with the skin. Winter is passed in the egg stage, and larvae are present from May to August. A common parasite is the tachinid *Leschenaultia fulvipes* (Bigot). *H. lucina* Henry Edwards feeds principally on spirea in the Northeast. *H. nevadensis* Stretch, the **Nevada buck moth**, is mainly a western species that feeds on poplar and willow. It occurs as far east as Wisconsin, Illinois, Nebraska, and Texas.

Royal moths constitute a subfamily of the Saturniidae and are medium-size to large, with stout bodies and large, strong wings *(1029)*. The head is generally sunken in the prothorax, and the male antennae are feathery for only a little more than half their length. The larvae are armed with horns or spines, and some are sparsely hairy. The horns or spines on the second and sometimes third thoracic segments are long and usually curved. The larvae feed on the foliage of various trees, and they pupate in the ground without forming cocoons.

The **spiny oakworm**, *Anisota stigma* (F.), feeds on oak and perhaps hazel from southern Ontario and Massachusetts to Florida and Texas. The adult has a wingspread of 45 to 62 mm. The wings are yellowish to rusty brown, sometimes tinged with pink, and heavily speckled in both sexes. Each forewing has a white spot. Full-grown larvae are about 37 to 50 mm long. The body is tawny brown, often tinged with rose or pink. It is covered with tiny ivory-white specks, denticles, or granules, and is marked indistinctly with single dorsal and lateral stripes. There are two long, curved spines on the second thoracic segment. The remaining segments bear backward-pointing black spines.

In the North, adults are present in June and July and the larvae from July to September. The winter is passed as a pupa in the ground, and there is one generation per year. This species is normally not very abundant, but infestations have occasionally covered several hectares.

The **orangestriped oakworm**, *A. senatoria* (J. E. Smith), feeds on various oaks from eastern Canada to Georgia and westward to Minnesota, Iowa, and Texas. It is rare in the Southeast. The adult has a wingspread of 37 to 50 mm, and its thick body is covered with yellowish-red hairs. The female (fig. 83A) looks like a small, faded, spiny oakworm, and the smaller, darker male has translucent areas in the forewings. The hindwings of the male are distinctly angular and only about two-thirds as long as the body. Full-grown caterpillars are black, with eight longitudinal orange-yellow stripes on the dorsum and sides; the larvae are about 40 mm long (fig. 83B). There is a pair of black, slender, stiff, erect, blunt, recurved spines on the second thoracic segment. Each succeeding segment bears a number of small, sharp, black spines.



Courtesy Conn. Agric. Exp. Stn.

Figure 83.—The orangestriped oakworm, *Anisota senatoria*: A, adult and eggs; B, larva.

In the North, adults appear during June or July and deposit their eggs in clusters of several hundred each on the undersides of leaves. Young larvae feed in groups on each side of the leaf, consuming everything but the veins. Older larvae are less gregarious and are often seen crawling around on lawns or the sides of houses, or feeding singly on the foliage of their host. During September or October, they crawl to the ground and often do considerable wandering in search of suitable places to pupate. Pupation takes place in the soil at a depth of 8 to 10 cm. There is one generation per year, possibly two in the South. This species has been responsible for a considerable amount of defoliation in oak stands in Connecticut, Missouri, New Jersey, and Pennsylvania. A similar species, *A. peigleri* Riotte, occurs commonly in the Piedmont of North Carolina, South Carolina, and Georgia (fig. 84).

The **pinkstriped oakworm**, *A. virginiensis* (Drury), occurs from southern Canada southward to Arkansas and Virginia. The larvae feed principally on various oaks, but also, perhaps, on many other hardwoods such as chestnut, hazel, maple, and birch. There is one generation per year. Adults (fig. 85) are yellow to reddish

brown, often with a purplish cast. Females have a wingspread of about 57 mm, males are considerably smaller. The forewings are thinner, less speckled, and more transparent beyond the discal dot than those of the orangestriped oakworm or the spiny oakworm. Full-grown larvae are about 50 mm long. The body is greenish gray with two dorsolateral, rose-colored stripes and a similarly colored stripe along each side. The entire body is covered with minute, white granules. Two spines on the second thoracic segment are slightly curved and are conspicuously longer than the others. Two similar species, *A. pellucida* (J. E. Smith) and *A. discolor* Ferguson, have two generations per year and occur on oaks throughout the Southeast and in Texas and Oklahoma, respectively.

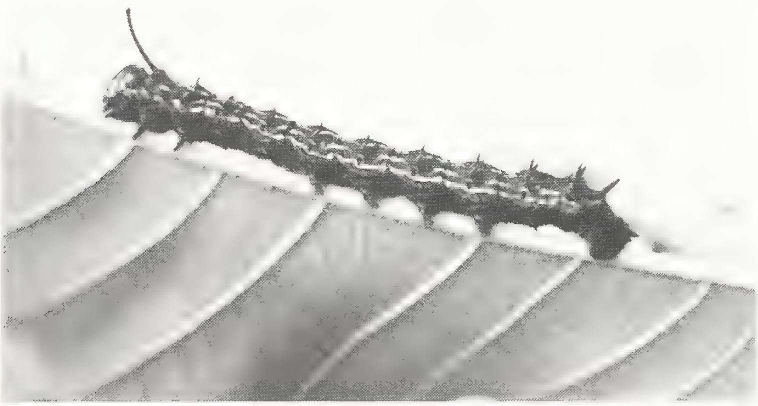


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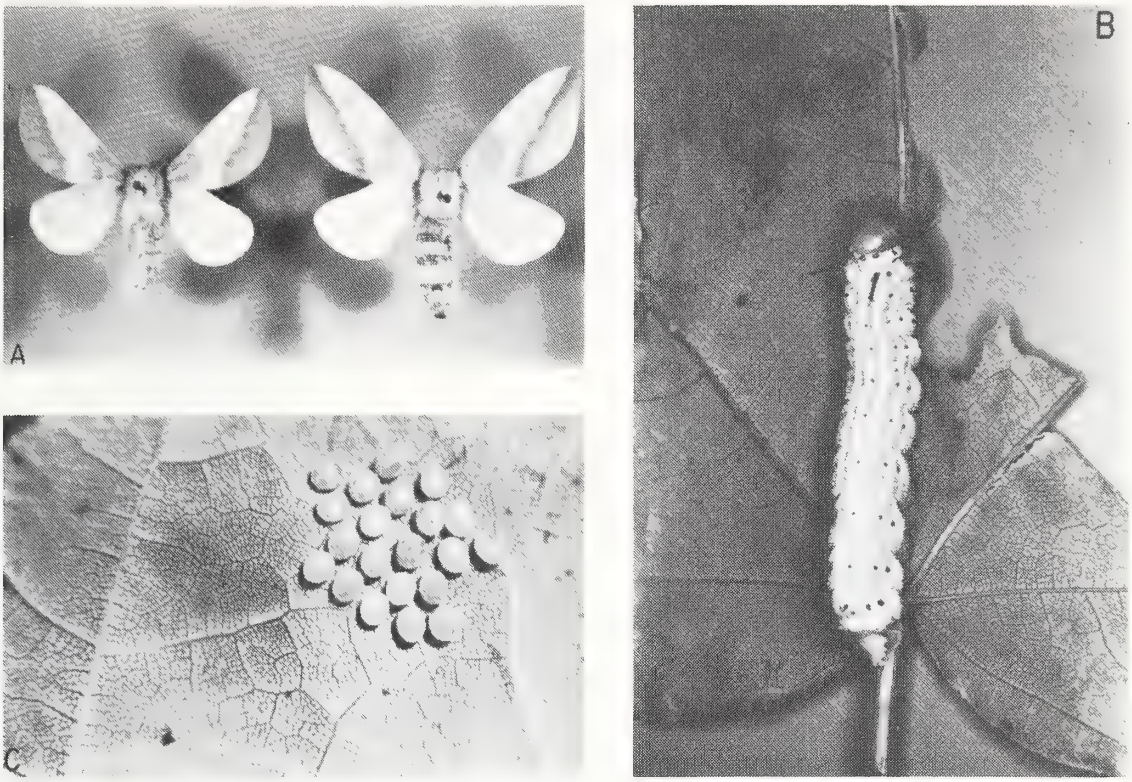
Figure 84.—Larva of *Anisota peigleri* found on chestnut in North Carolina.

Courtesy Duke Univ. Sch. For.

Figure 85.—Adult of the pinkstriped oakworm, *Anisota virginiensis*.

The **greenstriped mapleworm**, *Dryocampa rubicunda* (F.), is found throughout most of the Eastern United States and in adjacent areas of Canada. Its preferred hosts are maples, but it also feeds on various oaks and boxelder, especially where they are growing in mixture with maple. Populations may become heavy enough to cause serious defoliation anywhere within its range, but this is most likely to occur in the South. The moth (fig. 86A) has a woolly body and a wingspread of 37 to 50 mm. The body is yellow on top and rose-pink beneath. The forewing is rose-pink on the inner and outer borders with a yellow band between. The hindwings are either pure yellow, or yellow with rose-pink streaks. Pale, whitish forms are also known. Full-grown larvae (fig. 86B) have cherry-red heads, pale yellow-green

bodies, and are about 37 mm long. The body also has seven dark-green lines running its entire length, two prominent, slender horns on the second thoracic segment, two rows of short spines on each side of the body, and four larger spines on the terminal abdominal segments.



Courtesy D. C. Allen,
SUNY, Coll. Environ. Sci. & For.

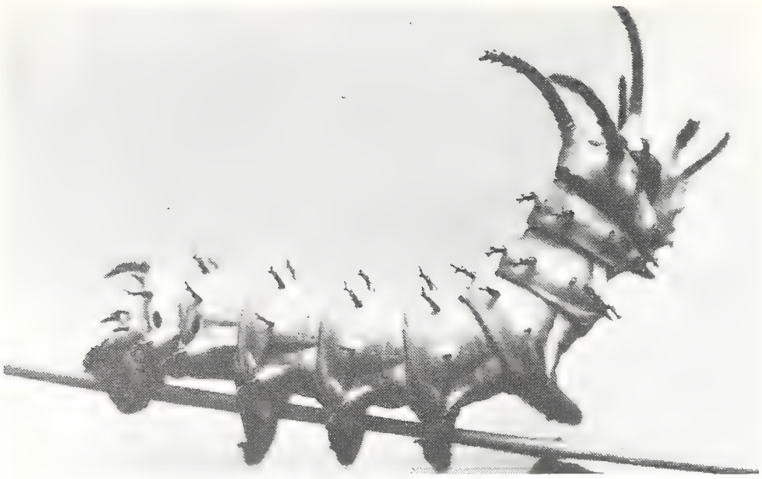
Figure 86.—The greenstriped mapleworm, *Dryocampa rubicunda*: A, male and female adults; B, fifth instar larva; C, egg cluster.

There is one extended generation per year in the North and two in the South. Eggs (fig. 86C) are laid on the undersides of leaves during May and June and hatch in about 10 days. Larvae feed singly, devouring entire leaves, and become full grown in about a month. With two generations in the South, trees may be defoliated twice in the same season. Full-grown larvae crawl to the ground and form cells in the soil or duff where they pupate and spend the winter.

Several species of parasites of the greenstriped mapleworm have been recorded, but never in any great abundance. Birds devour some of the larvae but are probably not very effective in population suppression *(9, 1321)*.

The **regal moth**, *Citheronia regalis* (F.), occurs throughout the Southern States, northward to Illinois and Massachusetts. The larva, known as the **hickory horned devil**, feeds on a wide variety of plants, including many species of trees such as hickory, walnut, butternut, persimmon, sweetgum, sycamore, ash, and sourwood. Adults are quite large; males have wingspreads of 100 to 125 mm, and females, 125 to 150 mm. The head and body are orange with pale-yellow markings; the forewings are olive-gray with reddish-brown veins and yellow spots and the hindwings are orange-red with somewhat redder veins. Full-grown larvae are 100 to 125 mm long and are startling to behold (fig. 87).

Adults appear in June and larvae are present from July to September. Winter is spent in the pupal stage in the ground. In most of its range there is only one generation per year, but in the Deep South there may be a partial second. This



Courtesy Conn. Agric. Exp. Stn.

Figure 87.—Hickory horned devil, larva of *Citheronia regalis*.

species is of little or no economic importance. It is of interest mostly because of the frightening appearance of the larvae.

Citheronia sepulcralis Grote & Robinson is occasionally found feeding on the needles of pines from Maine to Florida. Moths are dark brownish gray with a lilac tinge. There is a dusky discal spot on each forewing and a reddish base on the hindwing. The wingspread is about 75 to 100 mm. Full-grown larvae are dull brown, armed with short, orange horns, and are about 100 mm long.

The **imperial moth**, *Eacles imperialis* (Drury), occurs in the Eastern United States and southern Canada. The larvae feed on the foliage of a wide variety of trees including pines, redcedar, oaks, sweetgum, elm, persimmon, hickory, maple, beech, honeylocust, and baldcypress. The moth is sulfur yellow with brown and lilac markings and has a wingspread of 100 to 150 mm. Full-grown larvae are heavy-bodied and about 100 mm long. The head is orange-yellow with green sides; the body is pale green to dark green or reddish brown and sparsely covered with long, whitish hairs; it has short tubercles on the second and third thoracic and the last two abdominal segments. Adults appear during June and July and larvae are present from July to October. Winter is spent in the pupal stage in the ground; there is one generation per year in the North, two in the South.

Eacles imperialis pini Michener feeds on eastern white and jack pines in New York, Michigan, and southern Canada. The adults are smaller than those of the imperial moth and have dark markings of pink to pinkish brown. Spots on the wings are also heavier than those of the imperial moth. Adults are present from mid-June to mid-July.

Family Sphingidae
Sphinx Moths

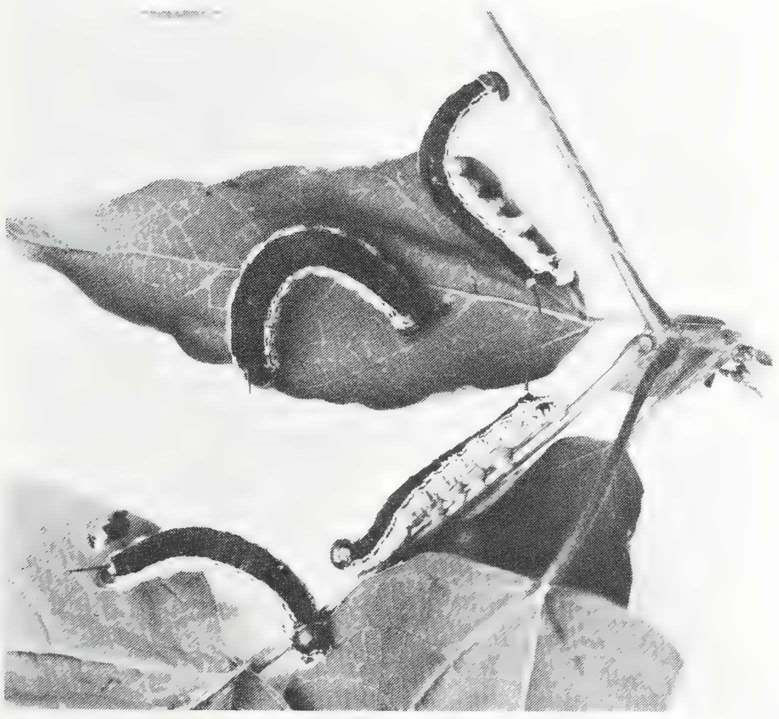
The adults of this family are distinctive in appearance and are known by such common names as sphinx moths, hawk moths, and hummingbird moths *(574, 1075)*. They have stout, spindle-shaped bodies and long, narrow, very strong wings. The antennae are more or less thickened at the middle or toward the tip and are usually pointed or curved back in the form of a hook. The mouth parts are usually very long, and when not in use are held coiled beneath the head like a watch spring. Mature larvae are long, usually naked, and each bears a horn, an eyelike spot, or a low tubercle on top of the eighth abdominal segment. The pose of the larva while at rest is distinctive—it clings to its support with its prolegs, holds the front part of the body aloft, and bends its head downward.

Sphinx moths are strong fliers. Some fly only at night, others at twilight or during the day. They are usually seen hovering like hummingbirds over flowers and feeding on nectar while in flight.

The **elm sphinx**, *Ceratomia amyntor* (Geyer), feeds on basswood, birch, and elm throughout the Eastern United States. Full-grown larvae are pale green to reddish brown; are marked on each side with seven oblique, whitish stripes; bear pairs of horns on the tops of the second and third thoracic segments; and have one caudal horn. They are about 75 mm long. *C. undulosa* (Walker), the **waved sphinx**, feeds on ash and lilac from eastern Canada and Maine to central Florida and westward to Texas and eastern Alberta. Full-grown larvae are about 62 mm long. The head is bluish green marked laterally by a broad, pale band. The pea-green body tapers toward the head and is marked by seven oblique, yellow stripes on each side; the spiracles are orange; and the caudal horn is reddish and curved toward the tip.

The **catalpa sphinx**, *C. catalpae* (Boisduval), occurs from New York to Florida and westward to Michigan, Kansas, Iowa, and Texas, but appears to be most abundant in the Southeastern States. It feeds exclusively on catalpa trees, often completely defoliating them. The injury is of relatively minor significance to the tree *(1157)*. The adult is heavy-bodied and has a wingspread of about 75 mm. The forewings and body are brownish with irregular dark and light bands and markings; the hindwings are almost uniformly brownish gray. Full-grown larvae are about 75 mm long and armed with a stout, black horn near the posterior (fig. 88). There are two highly variable color forms of large larvae—dark and light *(611)*. The dark form is black on top and pale yellow underneath; the light form is pale yellow with markings and patches of black on top.

Winter is spent as a pupa in the soil. Adults begin to appear as early as March in the South, but much later farther north. Eggs are deposited in large masses on the undersides of leaves or in smaller masses on twigs and branches. Young larvae feed



Courtesy OSU, Ohio Agric. Res. & Dev. Cent., Dep. Entomol.

Figure 88.—Larvae of the catalpa sphinx, *Ceratomia catalpae*.

gregariously; older ones, singly. In the Deep South, all life stages may be present during the summer, and there may be three or four generations per year. In the North there is only one generation per year. Larvae are often heavily parasitized by the hymenopteran *Cotesia congregata* (Say) (fig. 89).

Courtesy OSU, Ohio Agric. Res. & Dev. Cent., Dep. Entomol.

Figure 89.—Larvae of the catalpa sphinx parasitized by *Cotesia congregata*.

The **great ash sphinx**, *Sphinx chersis* (Hübner), feeds on lilac and ash throughout the United States. Full-grown larvae are usually light green with yellow-banded, bluish heads and are about 75 mm long. There are seven light-yellowish stripes, edged above with bluish green, on each side of the body, and the caudal horn is pale blue and curved downward. The larvae are found most commonly on young trees and sprout growth in the open or along roadsides. Populations are sometimes heavy enough to cause noticeable defoliation in such areas.

Sphinx kalmiae J. E. Smith, the **laurel sphinx**, feeds on white ash, fringetree, mountain-laurel, rhododendron, and lilac from southern Canada throughout the Atlantic States to Georgia and west to Saskatchewan and Mississippi. Full-grown larvae are yellowish green and about 75 mm long. The body is marked by seven oblique, yellow stripes edged above with black; the caudal horn is arcuate and blue with black, raised markings. *S. luscitiosa* Clemens feeds on poplar and willow in the Atlantic Coast States and west through the northern Plains. *S. drupiferarum* J. E. Smith, a widely distributed species, feeds on apple, cherry, hackberry, plum, and peach.

Eastern white, pitch, red, and jack pines are fed on by the larvae of *Lapara bombycoides* Walker, the **pine tree sphinx**, in eastern Canada and from the Atlantic Coast through the northern Plains. The larvae are present from July to September. Full-grown specimens are green except for a broad, brick-red, median dorsal stripe;

a reddish ventral stripe; and three longitudinal white stripes on each side. They are about 50 mm long. Brick-red patches sometimes enclose the spiracles, and there is no caudal horn. *L. coniferarum* (J. E. Smith) feeds on pines, especially longleaf and loblolly, in more southern areas.

Aspen, willow, and many other trees are fed on in the whole eastern area by *Paonias excaecatus* (J. E. Smith), the **blinded sphinx**. Full-grown larvae are light green, studded with pointed granulations, and about 62 mm long. There are seven oblique, yellowish stripes running backward on each side of the body; the head is conical, granulated, and has a white or pale-yellow stripe on each side, meeting at the apex. The spiracles are deep lilac or black; the caudal horn is usually green and nearly straight; and the thoracic legs are lilac or reddish. Larvae of *P. myops* (J. E. Smith), the **smalleyed sphinx**, feed on various kinds of cherry in the Eastern United States. They have rose-colored spiracles; otherwise, they closely resemble the larvae of *P. excaecatus*. The larvae of *Smerinthus jamaicensis* (Drury), the **twin-spot sphinx**, feed mostly on poplar and willow, but also on apple, birch, elm, and plum. They also resemble the larvae of *P. excaecatus*. They differ mainly in having a bluish-purple caudal horn and violet thoracic legs. Subdorsal rows of reddish spots may occur on each side of the body and around the spiracles in any of these three species.

The **walnut sphinx**, *Cressonia juglandis* (J. E. Smith), occurs from eastern Canada to Florida and westward to the eastern boundary of the Great Plains. The larvae feed on black walnut, butternut, the hickories, beech, and pecan. Full-grown larvae are light green to reddish, coarsely granulated with white, and about 50 mm long. The head bears a yellowish stripe on each side and two rough, brownish projections on the apex. There are seven light-yellowish oblique stripes, sometimes reddish bordered above, on each side of the body. The caudal horn is brownish and very granulated. There are two generations per year in the South.

Family Notodontidae
Notodontid Moths

More than 100 species of notodontid moths occur in the United States and Canada, and many of the larvae feed on the foliage of a wide variety of deciduous trees and shrubs. The family name refers to the fact that in some species there are backward-projecting tufts on the hind margin of the wings that protrude when the wings are folded. The larvae may be solitary, but many are nest builders. When disturbed, they often elevate each end of the body and remain attached by the four pairs of prolegs at the middle of the body. Larvae in some species spray a mixture of formic acid and other chemicals in response to attacks by predators *(377)*. These chemicals can burn human skin *(656)*. Many feed exposed on the foliage; others feed from within folded leaves or tents.

The **poplar tentmaker**, *Clostera inclusa* (Hübner), occurs in southern Canada and from New England to Georgia and Colorado, and feeds on various species of poplar and willow. The adult is brownish-gray with three whitish lines crossing each forewing, and it has a wingspread of about 25 mm. There is a crest of dark-brown hairs on the front of the thorax, and the hindwing is crossed by a wavy band. Full-grown larvae are brownish to nearly black and up to 42 mm in length. There are four lines of light yellow on top, and one bright and several indistinct lines and yellow marks are on the sides. Also, there are black tubercles on the tops of the first and eighth abdominal segments *(878)*.

Adults appear from March to April and from July to August, depending on location. Eggs are laid in clusters on the undersides of leaves. The larvae are

gregarious and live in tents or webs that they construct by pulling together the edges of one or more leaves and lining them with silk (fig. 90). They feed from May to October, then crawl to the ground and pupate in loose cocoons to spend the winter. Old, abandoned nests often remain on trees throughout the winter. There is one generation and a partial second or two per year in the North, and up to five in the South. This species often seriously defoliates small groups of trees, especially trees growing more or less in the open.

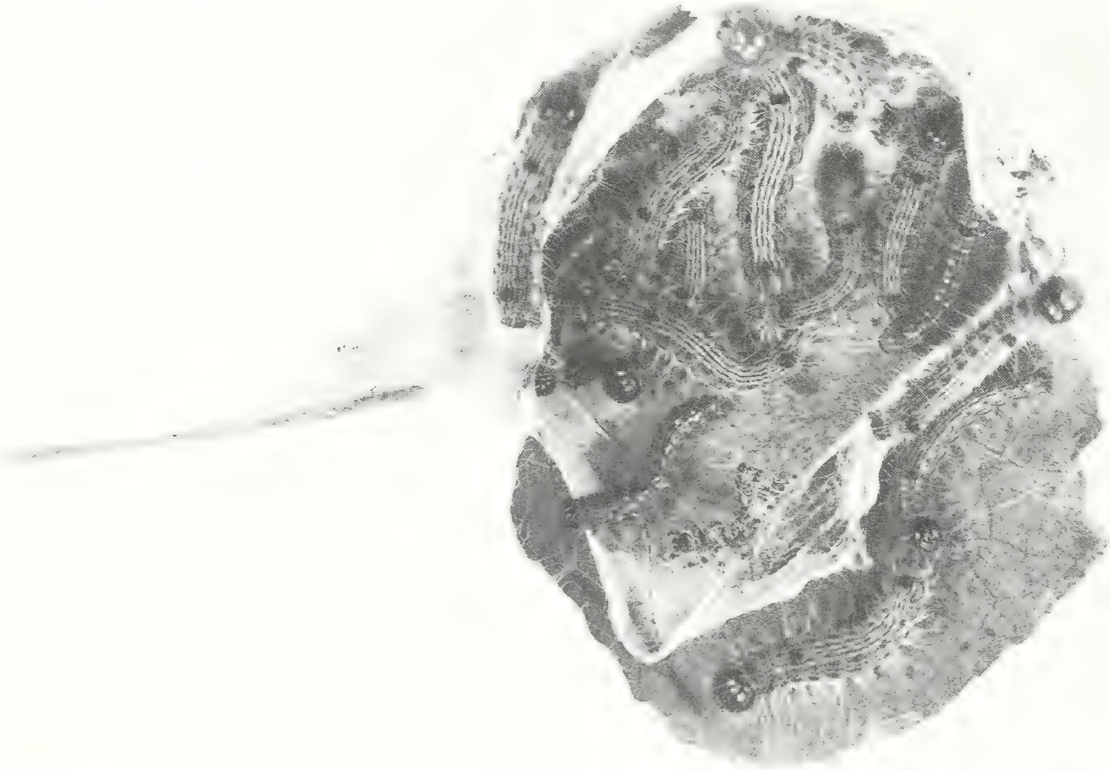


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Figure 90.—Nest of the poplar tentmaker, *Clostera inclusa*, torn open to show the larvae.

Other species of *Clostera* frequently encountered are *C. albosigma* (Fitch) on aspen; and *C. apicalis* (Walker), *C. brucei* (Henry Edwards), and *C. strigosa* (Grote) on aspen and willow. None is very important.

The **yellownecked caterpillar**, *Datana ministra* (Drury), occurs in southern Canada and throughout most of the Eastern United States. Its food plants include many species of fruit, shade, and forest trees. Important forest and shade tree hosts include paper and yellow birches, basswood, elm, oak, maple, butternut, walnut, mountain-ash, hophornbeam, and honeylocust. The adult has a wingspread of about 50 mm; its forewings are cinnamon brown and marked with irregular dark lines. Full-grown larvae are about 50 mm long and are moderately clothed with long, soft, white hairs. The head is jet black; the prothorax, bright orange-yellow; and the body, marked longitudinally with alternate black and yellow or whitish stripes.

Adults appear during June and July. Eggs are laid in masses of 100 or more on the undersides of the leaves. The larvae feed in colonies (fig. 91) near the ends of twigs and branches. When disturbed, they elevate both ends of the body. At maturity, they drop to and enter the soil to depths of 5 to 10 cm where they pupate and spend the winter. There is one generation per year *(1222)*.

Damage is seldom serious in the forest, although heavily infested trees may be completely defoliated. Fruit, shade, and ornamental trees are injured most severely.

Courtesy Ill. Nat. Hist. Surv.

Figure 91.—Cluster of larvae of the yellownecked caterpillar, *Datana ministra*.

Two species of tachinid parasites, *Compsilura concinnata* Meigen and *Winthemia datanae* Townsend, are important natural enemies.

Datana angusi Grote & Robinson feeds on hickory, oak, beech, gray birch, and butternut and occurs throughout the Eastern United States, west to Illinois, and along the north shore of Lake Erie in Ontario, Canada. Full-grown larvae resemble those of *D. ministra*, but differ in having an entirely black cervical shield *(644)*.

Datana perspicua Grote & Robinson, the **sumac datana**, feeds on sumac throughout most of the Eastern United States and in southern Canada. Full-grown larvae are moderately hairy and about 50 mm long. The head is dark reddish to black; the cervical shield, reddish brown; and the anal plate, blackish. The body is deep straw or lemon yellow, with 11 longitudinal, dark reddish-brown to blackish stripes.

Datana contracta Walker feeds on oak and sycamore in the Eastern United States west to the Lake States and Arkansas. Full-grown larvae are about 50 mm long and clothed with long, white hairs. The body is black with 11 longitudinal, yellowish-white stripes.

Datana drexelii Henry Edwards feeds on basswood, walnut, sassafras, and witch-hazel from the Atlantic Coast to Ohio. Full-grown larvae are moderately hairy and about 50 mm long. The head and body are black; the cervical shield and front of the thorax, honey-yellow; and the body bears 11 longitudinal stripes.

The **walnut caterpillar**, *D. integerrima* Grote & Robinson, occurs commonly in southern Ontario and throughout the Eastern United States where it feeds on a wide variety of deciduous trees, preferably walnut, butternut, pecan, and hickory. Adults are stout-bodied, have wingspreads of about 50 mm, and are clothed with dull-brown to chestnut-brown scales. The forewings are brownish and crossed by dark, irregular lines. Full-grown larvae may attain 50 mm in length. The body is black with longitudinal, yellowish stripes and is covered with long, white or dirty-gray hairs.

Adults are present during the spring and summer. Egg laying begins in early June, and eggs are deposited in masses on the undersides of leaves. The larvae feed in colonies until almost full grown (fig. 92). They are often found in masses on the trunk and larger limbs where they congregate to molt. Later, they return to the foliage to continue their feeding. Full-grown larvae drop to the ground and wander about searching for pupation sites. At this time they are often found in large numbers along the foundation walls of houses. Pupation occurs in the soil and there are one or two generations per year, depending on locality *(532)*.

Courtesy Ill. Nat. Hist. Surv.

Figure 92.—Colony of larvae of the walnut caterpillar, *Datana integerrima*.

The walnut caterpillar is frequently a serious pest of walnut. Trees heavily defoliated 2 or more years in succession are seriously injured or killed. Isolated trees or trees growing in small groups are especially subject to heavy attack. Losses have been particularly severe in the Central States *(391)*.

Datana major Grote & Robinson feeds on azalea and apple and various shrubs from the East Coast to Illinois. Full-grown larvae have mahogany-red heads, cervical shields, and legs. Their bodies are marked with longitudinal, yellow lines broken with black, giving them a finely spotted appearance.

Hyperaeschra stragula (Grote) has been recorded from southern Canada and the Northern States, where it feeds on willow and quaking aspen. Full-grown larvae are about 37 mm long. The head is flattened in front and slightly bilobed. The body is mostly pearly gray with a reddish-brown dorsal line between the head and second tubercle. The second and third abdominal segments each bears a conical tubercle directed backward, and there is a prominent, pale-rust hump on the eighth abdominal segment. Larvae are found from June to October, and the winter is spent as pupae in the ground. There are one and sometimes two generations per year.

Pheosia rimosa Packard, the **false-sphinx**, occurs rarely in eastern Canada and from coast to coast in the Northern United States. Its hosts are recorded as poplars, especially quaking aspen, and willow. Full-grown larvae are lead-colored with a

purplish tinge and about 43 mm long. The body segments are slightly smaller at the middle, and the eighth segment bears a well-developed horn. Larvae are present from July to October, depending on locality, and the winter is spent as a pupa in the ground. There may be one or two generations per year.

Lophodonta angulosa (J. E. Smith) occurs from southeastern Canada to Florida and Texas and feeds on various species of oaks. Full-grown larvae are pea green and about 37 mm long. The body is marked with a faint, double, whitish line down the middle of the back, and a distinct reddish stripe down each side. Larvae may be found from May to October, and winter is spent in silken cocoons on the ground. There are two generations per year in the South, but only one in the North. *L. ferruginea* Packard occurs on paper birch in the Northeastern States and southeastern Canada.

Nadata gibbosa (J. E. Smith), the **green oak caterpillar**, occurs from coast to coast in southern Canada and throughout the United States. The larvae feed on the foliage of a wide variety of deciduous trees such as various species of oaks, red and sugar maples, beech, paper birch, and willow. Full-grown larvae are pale pea green, have large, rounded heads and tapering bodies, and are about 43 mm long. The spiracles are deep red, and there is a yellowish stripe along each side. Larvae may be found from May to October, and winter is spent as a pupa beneath the litter, but not in the ground. There may be two generations per year as far north as New England.

Nerice bidentata Walker feeds on elm in southern Ontario and from New England to the Lake States and Kansas. Full-grown larvae are bluish green and about 30 mm long. There are four white bands on the front and sides of the head, and there is a large forward-pointing tubercle on each of the first eight abdominal segments, and a pair of small ones on the ninth. Larvae are present from June to September, and the winter is spent in silken cocoons on the ground. There is one or one and a partial second generation per year.

Symmerista canicosta Franclemont, the **redhumped oakworm**, occurs in southeastern Canada and throughout much of the Northeastern United States. Its hosts are various oaks, preferably white and bur, and several other deciduous trees such as basswood, sugar maple, paper birch, beech, and elm. Outbreaks covering several thousand hectares of oak type have occurred in Michigan and New England *(18)*. The adult is ash gray, with a long, white area near the outer two-thirds of the costal margin of each forewing, and it has a wingspread of 37 to 50 mm. The full-grown larva has a rounded, orange-red head and a yellowish body that increases in width back to an orange-red enlargement on the eighth abdominal segment. The body is also marked with five fine, black dorsal lines (fig. 93).

Adults appear from May to July and the female deposits her eggs in masses on the undersides of leaves. The larvae feed gregariously at first and skeletonize the foliage. Later, they scatter out and feed singly, devouring entire leaves except the larger veins. Mature larvae move to the ground and spin cocoons in rolled leaves where they pupate and spend the winter. There appears to be one generation per year.

Populations are usually too light to cause serious injury. Sometimes, though, they are heavy enough to cause severe defoliation in isolated spots.

Symmerista albifrons (J. E. Smith) occurs in the Eastern United States. Its hosts are much the same as those of the redhumped oakworm, a species with which it is easily confused both in appearance and habits. At least 5,000 hectares of northern hardwoods were defoliated in Upper Michigan and Wisconsin during an outbreak in

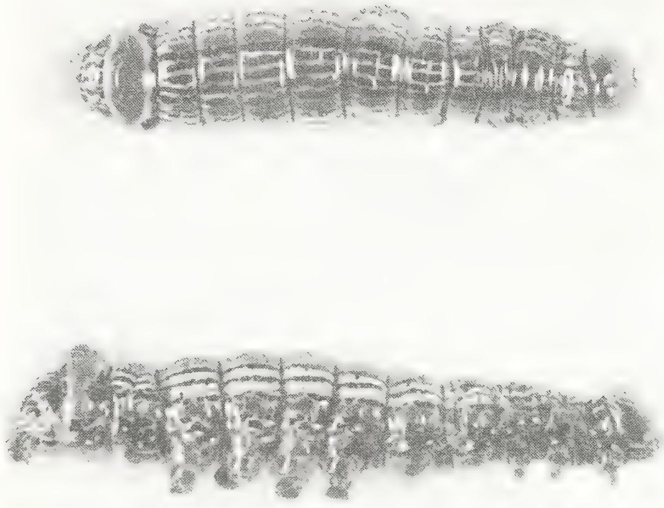

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Figure 93.—Larvae of *Symmerista canicosta*, the redhumped oakworm.

1961. There are two generations per year. The **orangehumped mapleworm**, *S. leucitys* Franclemont, occurs in the Northern States and southern Canada where it feeds principally on sugar maple. Its life history and habits are similar to those of the redhumped oakworm. It is distinguished from the latter by an orange headcapsule and hump and three fine, black dorsal stripes *(10)*.

The **variable oakleaf caterpillar**, *Heterocampa manteo* (Doubleday), occurs in nearly all of the States and Canadian provinces east of a line drawn from western Ontario through eastern Texas. Its hosts include a wide variety of deciduous trees. All species of oaks are attacked, but white oak is preferred. Other important species attacked include beech, basswood, paper birch, American elm, walnut, boxelder, persimmon, and apple *(1318)*. The adult is ashy gray and has a wingspread of 37 to 42 mm (fig. 94A). The full-grown larva is about 38 mm long with variable coloration. The head is large with two broad, lateral bands, the inner brown or black and the outer creamy white. The body is smooth, yellowish green with a pale, middorsal longitudinal line, and with more or less reddish-brown coloration on each side bordered laterally by a creamy-yellow stripe, below which is a yellowish, stigmatal stripe (fig. 94B).

Pupation occurs in early spring, and the adults appear from early May in the South to late May or early June in the North. Eggs are deposited singly on the leaves, each female laying up to 500. Young larvae skeletonize the lower surfaces of the leaves and older ones eat entire leaves, except the larger veins. Mature larvae move to the ground and spin cocoons in the litter or top soil. The larvae spray a chemical mixture containing formic acid, when disturbed. The mixture is capable of blistering the skin of humans *(656)*. Winter is spent in the prepupal stage. There are two generations per year in the South and one in the North.

Trees of all sizes are attacked, and heavy defoliation may occur anywhere in the insect's range, especially in the South. Some outbreaks have been extensive, covering thousands of square kilometers and extending for hundreds of kilometers *(1179)*. Tree mortality has usually not been serious, however, since most trees of sapling size or larger are able to withstand several years of extensive defoliation.

The **saddled prominent**, *H. guttivitta* (Walker), occurs in southeastern Canada and throughout the Eastern United States. Beech, yellow birch, and sugar maple are

its preferred hosts, but many other species of deciduous trees are fed upon in heavily infested stands. The adult is greenish gray or brownish gray with splotches of creamy white, and has a wingspread of about 50 mm. Full-grown larvae are usually green with reddish to purple or brown markings on the back, and they are about 30 mm long (fig. 95).

Adults emerge in late May or early July and the female deposits from 200 to 300 eggs singly on the lower surfaces of the leaves. Young larvae skeletonize the upper surface of leaves; older ones eat the entire leaf except the principal veins. They often migrate from tree to tree and, where abundant, may collect in large numbers about the bases of defoliated trees. Pupation occurs in the leaf mold from mid-July until late August. Winter is spent in the pupal stage. There is one generation per year in the northern parts of the insect's range.

Many outbreaks have been recorded since the turn of the century *(222, 961)* during which heavy defoliation occurred over large forested areas. In areas suffering two consecutive years of defoliation, considerable tree mortality occurred. Many of the trees that survived lost some of their large branches as well as large portions of their tops. The most damaging effects of defoliation of sugar maple occur to sapling and pole-size trees on poor sites *(504, 707)*.

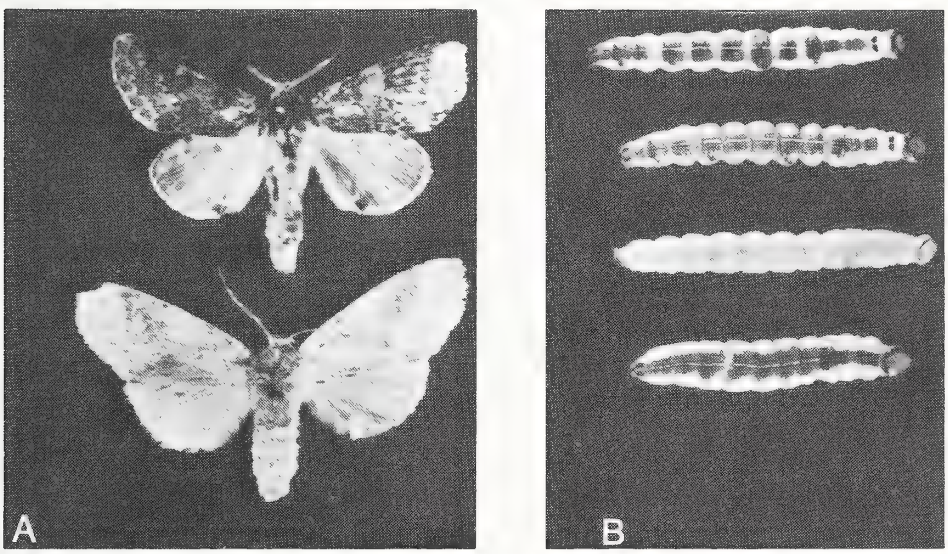

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Figure 94.—The variable oakleaf caterpillar, *Heterocampa manteo*: A, adults; B, larvae.

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Figure 95.—Dorsal and lateral views of larvae of the saddled prominent, *Heterocampa guttivitta*.

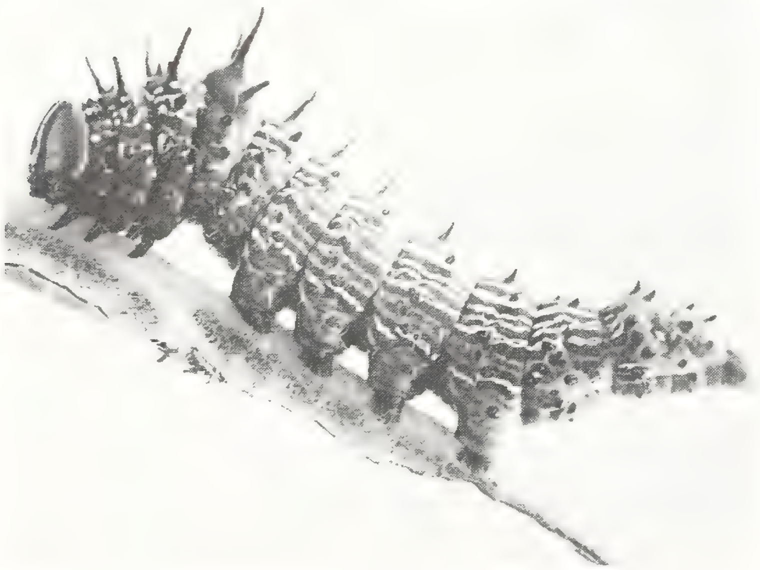
Several species of parasites have been reported from *H. guttivitta (8)*, but the most important are the egg parasite *Telenomus coelodasidis* Ashmead and the pupal parasite *Cratichneuman sublatus* (Cresson).

Other species of *Heterocampa* likely to be encountered in eastern forests include: *H. umbrata* Walker—on oak and maple; *H. biundata* Walker—on beech, paper birch, black cherry, and maple; and *H. bilineata* (Packard), the **elm prominent**—on elm and birch.

Macrarocampa marthesia (Cramer) occurs from Maine to Florida and Texas and feeds on the leaves of beech, maple, quaking aspen, oak, and sycamore. Full-grown larvae are pale green and up to 50 mm long. The head is flat in front; there is a small, double, reddish tubercle on the prothorax; and the body is marked with a longitudinal, yellowish-white stripe and occasional pink spots on the back. Larvae feed from July to October, then spin cocoons between leaves on the ground in which they pupate and spend the winter.

Oligocentria lignicolor (Walker) feeds on various species of oaks and beech throughout the Eastern United States. The larva is about 37 mm long and resembles larvae of the genus *Schizura*. Its prominent characteristics include a pale, bilobed head, with dark branched bands on each side of the face meeting on the vertex. There is also a large, slightly cleft tubercle on the first abdominal segment and a smaller brownish one on the eighth abdominal segment. The sides of the thorax are pea green. Adults appear in July and August in the Northeastern States; the larvae, from August to October. Winter is spent in a tough, parchmentlike cocoon on the ground.

The **redhumped caterpillar**, *Schizura concinna* (J. E. Smith), occurs throughout the United States and in most of the Canadian provinces. Its hosts include fruit trees and a long list of forest and shade trees, such as elm, quaking aspen, willow, hickory, black locust, dogwood, sweetgum, persimmon, and paper birch. The adult is grayish brown and has a wingspread of about 50 mm. Full-grown larvae are about 25 mm long. The head and a hump on the eighth abdominal segment are red; the body is marked with black and yellowish lines and bears a double row of short, stout, black lines on top (fig. 96). When at rest, the larva holds the rear end in an elevated position and, when handled, it gives off a pungent, disagreeable odor.



Courtesy Conn. Agric. Exp. Stn.

Figure 96.—Larva of the redhumped caterpillar, *Schizura concinna*.

Adults appear from late May to August, depending on locality. Eggs are laid in masses containing up to 100 each on the undersides of leaves. The larvae are gregarious. At first, they skeletonize the undersurfaces of the leaves. Later, they devour entire leaves except the midrib. During their feeding, they completely defoliate one branch before moving on to another. Mature larvae move to the ground and construct parchmentlike cocoons in the duff in which to spend the winter. There is one generation per year.

Populations are often heavy in unsprayed apple orchards, along roadsides and fence rows, and on ornamentals. In light infestations or on ornamentals, it is often practicable to collect and destroy the colonies as soon as they are discovered.

Three other eastern species of *Schizura* are sometimes common locally: the **unicorn caterpillar**, *S. unicornis* (J. E. Smith), *S. leptinoides* (Grote), and *S. ipomoeae* Doubleday. Each species feeds on a wide variety of hosts, such as apple, pin cherry, elm, quaking aspen, hickory, beech, paper birch, and willow.

Gluphisia septentrionalis Walker occurs in southeastern Canada and the northern portions of the Eastern United States. It feeds on various poplars, especially quaking aspen. Full-grown larvae are pale green and about 37 mm long. The head has blackish stripes on each side; the body is largest in the middle, and is marked with pinkish to reddish blotches on the back and a yellow line along each side. Larvae are found from June to September, and winter is spent in cocoons on the ground. As a rule, there is one generation per year, but in some localities there may be two.

The genus *Cerura* is represented in eastern forests by *C. borealis* (Boisduval), *C. occidentalis* Lintner, *C. cinerea* Walker, and *C. multiscripta canadensis* McDunnough. The first feeds on quaking aspen, willow, and black cherry; the last three on quaking aspen and willow. *Notodonta simplaria* Graef also feeds on quaking aspen and willow. *Misogada unicolor* (Packard) occurs on sycamore, and *Hyparpax aurora* (J. E. Smith) and *H. perophoroides* (Stecker) are found on oak.

Family Arctiidae
Tiger Moths and Allies

This is a large family of stout-bodied moths with moderately broad wings. In general they are moderate in size and have broad heads and pectinate or ciliate antennae. Many species are marked with brightly colored spots and stripes. All are night fliers and are attracted to lights. They usually fold their wings rooflike upon the abdomen while at rest. The larvae of most species are clothed with dense clusters of hairs. In some species, certain of these clusters are larger and longer than others, causing the larvae to resemble those of the tussock moths in the family Lymantriidae. The hairs of certain species are irritating to humans. The majority of species prefer the foliage of low-growing plants, but a few feed on the foliage of trees and shrubs.

The **hickory tussock moth**, *Lophocampa caryae* (Harris), occurs in southern Canada and south in the Eastern States to North Carolina. The larvae feed on the foliage of a wide variety of deciduous trees and shrubs including walnut, butternut, hickory, birch, elm, black locust, basswood, and quaking aspen. Walnut, butternut, and hickory appear to be preferred. Adults are light brown or buff, with numerous silvery-white spots on the forewings, and they have wingspreads of about 50 mm. Full-grown larvae are about 37 mm long. The body is clothed with short, spreading tufts of grayish-white hairs. There is a row of black tufts on the first eight abdominal segments and pairs of long, black, hair pencils on the first and seventh abdominal segments (fig. 97).

Courtesy Can. For. Serv., Can. Dep. Environ.,
Sault Ste. Marie, Ont.

Figure 97.—Larvae and cocoon of the hickory tussock moth, *Lophocampa caryae*.

Adults appear from late May to early July. The female deposits her eggs in batches of 50 to 400 each in a single layer on the undersides of leaves. The larvae feed gregariously until nearly mature. Winter is spent in the pupal stage in gray, hairy cocoons under rubbish and stones on the ground. There is one generation per year. This species is often abundant locally, but it seldom, if ever, causes serious defoliation.

The **spotted tussock moth**, *L. maculata* (Harris), occurs in the Northern States and southern Canada. The larvae feed on the foliage of various deciduous trees such as oak, poplar, birch, beech, black locust, boxelder, black cherry, maple, and willow. The oaks, willow, and poplar are particularly favored. The adult is pale yellow with long, somewhat pointed, brown-spotted forewings, and has a wingspread of 37 to 50 mm. Full-grown larvae are about 30 mm long, and dull black above. They are thickly clothed with tufts of black and bright-yellow to whitish hairs, and have a row of short tufts down the middle of the dorsum. The tufts on the third thoracic and eighth abdominal segments are longest and bear an intermixture of white, yellowish, and black hairs; those on the thorax overhang the head. The larvae are solitary feeders except during outbreaks and are found from July to October. Winter is spent as a pupa in a hairy cocoon, and there is one generation per year. This species is occasionally abundant enough to damage shade trees.

The **pale tussock moth**, *Halysidota tessellaris* (J. E. Smith), occurs in southern Canada and throughout the eastern part of the United States. The larvae feed on practically all common deciduous trees and shrubs. The adult is pale yellow and has a wingspread of about 50 mm. The forewings are translucent and crossed by five broad, dark bands. Full-grown larvae are dingy and densely clothed with compact tufts of light-yellow or dirty-white fine hairs. Hair pencils rise in pairs from the second and third thoracic and eighth abdominal segments (fig. 98). Adults appear in June and July and the larvae, which usually feed singly, are present from August to October. The winter is spent as a pupa in a brownish, hairy cocoon, and there is one generation per year. This species is frequently abundant in the forest and along roadsides in the South Central States, but is usually of minor importance.

Courtesy Conn. Agric. Exp. Stn.
Figure 98.—Larva of the pale tussock moth, *Halysidota tessellaris*.

The **sycamore tussock moth**, *H. harrisii* Walsh, feeds on sycamore and London plane trees, and it probably occurs wherever sycamore grows in this country. Adults are indistinguishable from those of the pale tussock moth, and the larvae of the two species differ only in color. Larvae of this species have yellowish bodies clothed in whitish to yellow hairs, and the long hair pencils are orange. Infestations are often heavy on shade and ornamental sycamore in the Northeast.

The **fall webworm**, *Hyphantria cunea* (Drury), occurs throughout the United States and southern Canada. Its hosts include more than 100 species of forest and shade trees. The adult has a wingspread of 30 to 42 mm, and the bases of the front legs are orange or bright yellow. In the southern part of its range, the moth is white, usually with dark spots on the wings. In the North, particularly in eastern Canada, it is nearly always pure white and was formerly referred to as *H. textor* Harris. Full-grown larvae are usually pale yellowish or greenish, with a broad, dusky stripe down the back and a yellowish stripe down each side. They are about 25 mm long. Their bodies are covered with long, silky, gray hairs arising in tufts from orange-yellow or black tubercles. Head color varies from red to black. The larvae of *H. textor* are dark.

Adults appear mostly from May to July and deposit their eggs in hair-covered masses of several hundred each, usually on the undersides of leaves. Newly emerged larvae immediately begin to spin a silken web over the foliage on which they feed; as they grow, they enlarge the web to enclose more and more foliage (fig. 99). On heavily infested trees several branches may be enclosed in webs. Small trees are often enclosed entirely. The larvae are gregarious until the last instar. During the early stages, they feed on the upper surface of the leaves; later they devour entire leaves except the larger veins and midribs. As they approach maturity, some larvae leave the web and feed individually. Pupation occurs in thin cocoons usually spun in the duff or just beneath the surface of the soil. There are one to four generations per year, depending on location.

The fall webworm is ordinarily of no great importance as a forest pest since it usually attacks understory weed species of no economic value. Outbreaks may

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Figure 99.—Defoliation and webbing caused by the fall webworm, *Hyphantria cunea*.

occur, however, sometimes encompassing tracts of several square kilometers. The fall webworm is often a serious pest of shade trees and ornamentals. These trees may be heavily or completely defoliated, and the presence of numerous, unsightly webs is esthetically detracting. Persistent infestations on individual trees may cause branch and top-kill. There is considerable literature on this insect in the United States and Canada *(185, 881, 883, 884, 946, 947, 1207).*

Seirarctia echo (J. E. Smith) larvae feed on the foliage of persimmon, runner oak, and cabbage palmetto from Florida to Mississippi. The adult is white and has a wingspread of about 55 mm. The wing veins are edged with dark brown or black. Full-grown larvae are clothed with coarse, black-tipped hairs and are about 50 mm long. The body is black on top except for a pair of yellowish stripes and a row of orange warts that cross each segment.

Other species of arctiids likely to be encountered in eastern forests include: *Haploa clymene* (Brown)—on maple, hickory, and apple; *H. lecontei* (Guérin-Méneville)—on maple, birch, oak, and cherry; *Apantesis radians* (Walker)—on slash pine seedlings in Georgia; and *Lexis bicolor* Grote—on balsam fir and spruce.

Family Ctenuchidae
Ctenuchids

Lymire edwardsii (Grote) has been recorded feeding as larvae on the foliage of banyan and fig trees in Florida. The adult is a sluggish, bluish-gray to purplish-gray moth, with plumose blue antennae. The thorax is orange-red beneath, the abdomen white beneath and blue above. Larvae are somewhat whitish with a dark tuft of hairs on the thorax. When touched, they usually flip from the leaf and drop to the ground on silken threads. This species is occasionally destructive on shade or ornamental trees *(469).*

Family Lymantriidae
Tussock Moths

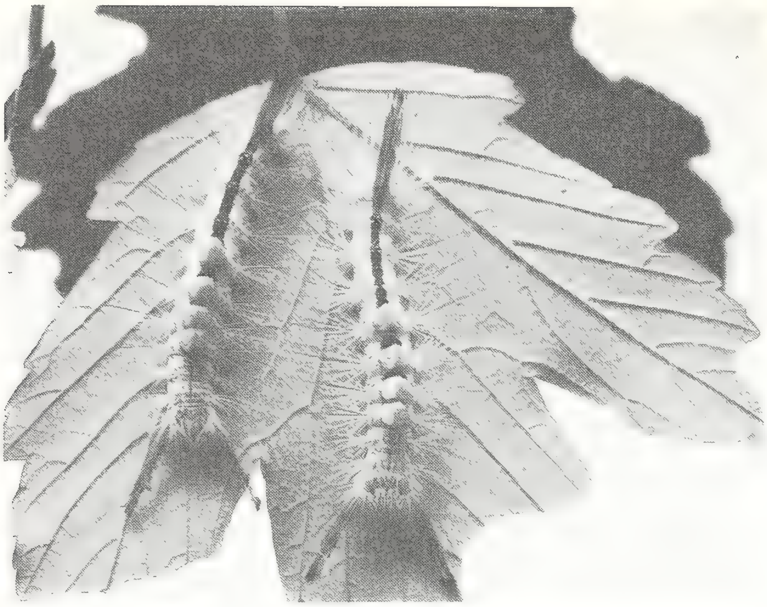
This family includes some of the insects that most seriously defoliate trees in the United States. The female moths of certain species are wingless; others, though winged, are so heavy-bodied that they are either unable to fly, or can fly for only short distances. The remainder are strong fliers. The females of some species pack and cover their eggs with their abdominal hairs; others coat their eggs with a viscid secretion that hardens and forms a protective covering. The urticating hairs of certain species in all stages may cause allergic reactions in people when they come in contact with skin. The larvae of our native species also bear conspicuous tufts of hairs on top of certain body segments.

The **rusty tussock moth**, *Orgyia antiqua* (L.), occurs throughout southern Canada and in the northern part of the United States. Its hosts include scores of species of both deciduous and coniferous trees *(404)*. The male adult is rusty colored. The forewings are crossed by two darker bands and each bears a conspicuous white spot near the border. Females are gray and wingless. Full-grown larvae are about 28 mm long and have black heads and dark-gray bodies. The second abdominal segment bears a black hair pencil on each side, and there are reddish-orange tubercles bearing hairs. The tufts on the prothorax and abdomen are similar to those on the larvae of the whitemarked tussock moth. The female deposits her eggs in a single-layered, naked mass on the cocoon from which she emerges. There are one and possibly two generations per year. This species is sometimes abundant locally. Conspicuous defoliation has been recorded in Canada.

The **whitemarked tussock moth**, *O. leucostigma* (J. E. Smith), occurs commonly throughout the Eastern United States and eastern Canada and feeds on a wide variety of deciduous and coniferous trees. Preferred species appear to include the following: apple, basswood, elm, and poplar; Norway, silver, and planetree maples; sycamore; paper and yellow birches; larch; and balsam fir. The female adult is wingless, grayish to light brown, hairy, and about 12 mm long. Males are ashy gray, and have fully developed wings with a wingspread of about 30 mm. The forewing has a conspicuous white spot near the anal angle, and is marked with dark wavy bands. Full-grown larvae (fig. 100) have coral-red heads and thoracic shields, yellow to cream-colored bodies, and are about 25 to 37 mm long. There is a pair of upright pencils of black hairs on the prothorax and another black tuft on the eighth abdominal segment. There are also brushlike tufts of white or yellowish hairs on each of the first four abdominal segments and reddish dots on the sixth and seventh segments. The sides of the body are clothed in white and blackish hairs radiating from rows of small yellow tubercles.

Winter is spent in the egg stage and hatching occurs between April and June. Young larvae feed on the surface of the leaves, skeletonizing them. Later, they chew holes in other leaves and finally consume all but the larger veins. Young larvae often spin down on silken threads and are sometimes transported considerable distances by the wind. The larvae become full grown in 5 or 6 weeks, then, under branches or in bark crevices, they spin grayish cocoons consisting of silk and hairs from their bodies. The pupal stage lasts about 2 weeks. Usually there are two generations per year.

The whitemarked tussock moth may be a pest of shade trees in cities and towns. It also occurs in forested areas but usually causes minor damage there. The life history, habits, and parasites of the species are discussed *(404, 609)*.



Courtesy Conn. Agric. Exp. Stn.

Figure 100.—Larvae of the whitemarked tussock moth, *Orgyia leucostigma*.

Orgyia definita Packard, the **definite-marked tussock moth**, occurs in southern Ontario and the Eastern States and feeds on quite a wide variety of deciduous trees such as willow, apple, pin cherry, elm, paper birch, red oak, red maple, and ash *(404)*. The adults and larvae closely resemble those of the whitemarked tussock moth in form and size, and in the arrangement of the tufts of hairs on the larvae. Wingless females are clothed in golden-brown hairs. They lay their eggs in masses on the cocoons from which they emerge, covering them with hairs from their bodies. In addition to the conspicuous pencils and tufts of hair, the larva is yellow, with a faint dorsal stripe and a black spot behind each of the second and third tufts of hair on the abdomen. This species is seldom of economic importance.

The genus *Dasychira* is represented in eastern forests by a number of species, a few of which are economically important. Adults of the different species are very similar in appearance and are difficult to distinguish. In both sexes they are winged, and the females are heavy-bodied. The larvae have tufts of hairs characteristic of the tussock moth group and their bodies are densely clothed with hairs. In some species there is a feathery black hair in each lateral tuft.

Dasychira basiflava (Packard), the **dark tussock moth**, is sometimes locally common in the Eastern States, where it feeds on various deciduous trees such as slippery elm, white oak, beech, flowering dogwood, and hickory. The head of the larva is hidden by yellowish clusters of barbed spines, and there are tufts of hairs on the first and fourth abdominal segments. Heavy infestations on valuable shade and ornamental trees may cause serious damage. It has several natural enemies including parasites and pathogens *(655)*.

The **pine tussock moth**, *D. pinicola* (Dyar), occurs in the Northeastern States west to the Lake States and in southeastern Canada. The larvae feed on various conifers such as jack, red, and eastern white pines, spruce, and balsam fir. Jack pine is especially favored. The moth is gray-brown with lighter and darker stripes across the forewings, and has a wingspread of 25 to 37 mm. Full-grown larvae are gray-brown and about 37 mm long. There are four tufts of grayish or brownish hairs on the dorsum. The first tuft has two black hair pencils on the front and three similar ones on the rear.

Adults are present from early July to early August in the Lake States. Eggs are usually deposited in small, irregular clusters on or near the female pupal case, mostly on the needles near midcrown but also on the trunk, dead twigs, and similar vegetation. Young larvae feed on the flat surfaces of needles. During August, the second or third instars spin a few silken threads about themselves and go into hibernation. They may be found beneath rough bark on large trees or between the bases of needles on young, smooth-bark trees. Feeding is resumed in the spring on staminate flowers and young needles. Later, old needles are also attacked, with everything being consumed down to the needle sheath. In heavy infestations, the entire tree may be completely defoliated. Full-grown larvae spin silken cocoons on twigs or among needles. There is one generation per year *(1237)*.

Several extensive outbreaks have occurred in the Lake States since the turn of the century, and losses, especially of jack pine, have been serious. During 1961-62, outbreaks covering several hundred square kilometers of jack and red pines and white spruce were recorded in the region.

Other eastern species of *Dasychira* and their hosts are as follows: *D. plagiata* (Walker)—on conifers at high elevations in the Appalachians, northern Massachusetts into Canada and west to the Rocky Mountains *(1143)*; *D. obliquata* (Grote & Robinson) and *D. vagans* (Barnes & McDunnough)—a willow and poplar defoliator; *D. meridionalis* (Barnes & McDunnough)—on oak in the Southeast; *D. cinnamomea* (Grote & Robinson)—on elm from New England to the Lake States; *D. tephra* Hübner—on oak in the Southeastern States; *D. dorsipennata* (Barnes & McDunnough)—on oak in Maine and southern Canada.

The **gypsy moth**, *Lymantria dispar* (L.), was introduced into the United States in 1869 when a French scientist brought a number of egg clusters from France for the purpose of crossing the species with the silkworm. During the course of his work, larvae escaped, and the species became established. About 20 years later, caterpillars had spread over an area of about 900 square kilometers around Boston, and shade and fruit trees were being completely defoliated. The gypsy moth has continued to spread and now occurs throughout the New England States, except northern New Hampshire and Maine, and northeastern Vermont. It also occurs in New Jersey, New York, Pennsylvania, Delaware, Maryland, Michigan, Virginia, and southern parts of Ontario and Quebec. Relatively small, isolated infestations have occurred in Arkansas, California, Illinois, Nebraska, North Carolina, Oregon, and Wisconsin. Adult males have been trapped in numerous other States. Its hosts include most species of hardwoods, the oaks, apple, basswood, willows, birches (except yellow and sweet), and poplars being most highly favored. Several conifers are also attacked, usually when growing in mixture with the more highly favored hardwoods *(42)*. A list of food plants, divided into groups by host preference, has been published *(893)*.

The general biology of the gypsy moth has been reported by several authors *(16, 727, 928)*. The male of the gypsy moth (fig. 101A) is dark brown, with blackish bands across the forewings, and has a wingspread of about 37 mm. Females (fig. 101B) are almost white and have wingspreads of about 50 mm. The abdomen of the female is clothed in yellowish hairs and is so large and heavy that she is unable to fly. Full-grown larvae (fig. 101C) are about 37 to 60 mm long. The head has yellow markings, the body is dusky or sooty-colored and hairy, and there is a double row of five pairs of blue spots followed by a double row of six pairs of red spots on the dorsum. The pupa (fig. 101E) is reddish brown with a sprinkling of reddish hairs.

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Figure 101.—Life stages of the gypsy moth, *Lymantria dispar*: A, adult male moth; B, adult female moth; C, mature larva; D, egg mass; E, female pupa with cast larval skin.

Adults appear in late July and August, and mate. The males fly vigorously in a zigzag manner, often within about 1 m of the ground. The females, being unable to fly, crawl a short distance from the empty pupal case and mate. Immediately after mating, they lay their eggs in oval masses (fig. 101D), about 100 to 1,000 eggs each, then cover them with buff-colored hairs from their abdomens. While the majority of the masses are deposited on the trunks and limbs of trees, many are also laid in various other places such as under stones, inside hollow stumps and trees, on leaves, and even on buildings. Some masses are deposited on vehicles, and this accounts for the long-distance dispersion of the gypsy moth. The winter is spent in the egg stage, and hatching occurs about the first of May, usually about the time oak leaves unfold.

Young larvae crawl from the egg mass and move toward the tops of trees. During this period they often spin down on silken threads, especially when disturbed, and some may be transported by the wind *(221, 824)*. Newly hatched larvae feed first on leaf bases, then on the leaf surfaces, chewing small holes in the leaves. Older larvae feed almost entirely from the edge of the leaf. During this part of their lives, they feed mostly at night and tend to congregate in sheltered places during the day *(436)*. Large larvae consume entire leaves except the larger veins and midribs. In heavily infested stands the entire crop of foliage may be consumed before the larvae

reach maturity. When this happens, the larvae usually vacate the trees and often migrate in search of food. When the food supply is depleted but not completely consumed before the larvae mature, many succeed in pupating but they are smaller than normal. This results in smaller than normal adults, and the number of eggs deposited per female is greatly reduced. Larvae seek sheltered places in which to pupate. Pupae may be found attached by silken threads to limbs and trunks of trees, stones, picnic tables, forest debris, buildings, vehicles, and the like. In heavy infestations, they are often found massed together in large numbers. The pupal stage lasts about 10 days or 2 weeks.

The gypsy moth has long been considered one of the most important forest insects in the United States. Since the turn of the century, enormous sums of money have been expended by the Federal Government and the affected States to eradicate it, to suppress it, or to prevent its further spread *(810)*. Despite these efforts, outbreaks have continued to occur in the older infested portions of New England often at 8- to 10-year intervals *(19)*, and have expanded to newer infested areas to the South and West (table 1).

Defoliated trees show reduced growth and are more susceptible to attack by wood-boring insects and fungi than are undefoliated trees *(249, 348, 608, 702, 1245, 1246)*. Mortality of defoliated trees has been variable *(191, 660, 702, 1156)*. Further losses result from the reduction in quality of forest sites in stands suffering repeated defoliations. Esthetic and recreational values are also reduced in outbreak areas.

When the gypsy moth was introduced, the insect parasites, predators, and pathogens affecting it in its native habitats abroad were left behind, and it encountered none in the Northeast that were capable of holding it in check. To remedy this situation, a program of importation of foreign parasites and predators was initiated in 1905 and has been continued intermittently to the present *(252, 328, 613, 618, 1014)*. Collections representing 45 different species of the parasites and predators were imported, colonies of which were released in infested stands in this country. Ten species of parasites and two predators became established *(618, 1090)*. Two are hymenopterous egg parasites—*Ooencyrtus kuvanae* (Howard) and *Anastatus disparis* Ruschka; four are tachinid larval parasites—*Compsilura concinnata* (Meigen), *Exorista larvarum* (L.), *Parasetigena silvestris* (Robineau-Desvoidy), and *Blepharipa pratensis* (Meigen); two are hymenopterous larval parasites—*Phobocampe disparis* (Viereck) and *Cotesia melanoscelus* (Ratzeburg); two are hymenopterous pupal parasites—*Monodontomerus aereus* Walker and *Brachymeria intermedia* Nees; and two are coleopterous predators—*Calosoma sycophanta* (L.) and *Carabus auratus* L.

One of the most important factors affecting heavy gypsy moth populations is the so-called wilt disease, caused by a nuclear-polyhedrosis virus. This pathogen is also a native of Europe. It may have entered this country in gypsy moth material imported for the recovery of parasites. During moth epidemics, it increases tremendously and decimates populations over large areas *(312, 731, 990)*. Other natural control factors include low winter temperatures—exposed eggs begin dying at a temperature near $-28°$ C *(481, 1178)*. Small mammals devour large larvae and pupae found on the forest floor. Also, many larvae die of starvation in woodlands entirely stripped of foliage before the larvae reach maturity. Discussions of the population dynamics and ecology are available *(104, 187, 189, 726, 1106)*.

Silvicultural practices designed to promote the health and vigor of stands are helpful in increasing tree resistance to gypsy moth damage *(105)*. A reduction in the

Table 1. Periodic gypsy moth defoliation in various States, 1925-82.

Year	Hectares defoliated												
	Maine	N.H.	Vt.	Mass.	R.I.	Conn.	N.Y.	Pa.	N.J.	Del.	Md.	Mich.	Total
1925	---	97	0	19,556	0	0	0	0	0	0	0	0	19,653
1930	22,329	83,014	0	11,273	27	2	0	0	0	0	0	0	116,645
1935	37,487	133,630	43	42,937	4,414	337	0	0	0	0	0	0	218,848
1940	82,575	61,837	1,279	50,825	21	0	0	0	0	0	0	0	196,537
1945	85,344	23,682	38,022	184,880	518	6	0	4	0	0	0	0	332,456
1950	1	5	0	2,015	0	152	0	0	0	0	0	0	2,173
1955	4,374	6,060	3,592	0	0	2,769	4,273	0	0	0	0	0	21,068
1960	2,570	1,862	2,482	61	0	6,071	6,674	0	0	0	0	0	19,720
1965	77	3,420	1,175	6,974	20	34,808	60,044	0	0	0	0	0	106,518
1970	437	15,591	0	2,766	438	[1]149,215	168,464	4,249	52,544	0	0	0	393,704
1975	45	0	6	7,242	176	25,662	3,754	128,646	22,433	0	0	0	187,964
1980	89,563	74,494	30,402	367,237	17,745	110,208	991,690	178,340	166,792	0	1	2	2,026,474
[2]1981	262,336	778,894	19,592	1,130,438	109,022	592,886	921,566	1,011,101	319,516	200	3,530	7	5,149,088
1982	232,606	355,576	3,994	560,026	266,556	325,426	334,296	951,950	273,678	512	3,709	37	3,308,366

[1] Includes defoliation by the elm spanworm.
[2] Year of most widespread defoliation.

proportion of favored host species also decreases the chance of infestation and limits the degree of population buildup *(84)*.

Insecticidal spraying by aircraft has been used widely in gypsy moth control. Various chemical insecticides are effective. Attempts to secure control by spraying infested stands with the nuclear-polyhedrosis virus continue with some success *(733, 989, 1033)*. Spraying with the microbial insecticide, *Bacillus thuringiensis* Berliner *(25, 343)*, has given foliage protection. Another possible method of control is the use of synthetic sex attractants. The natural female attractant has been isolated, identified, and synthesized *(106, 626)*; the synthetic pheromone is known as disparlure. It has been particularly useful in survey and detection work *(1072)*. The use of the sterile-male technique for controlling gypsy moth continues to be investigated *(827, 1073)*.

The **satin moth**, *Leucoma salicis* (L.) (fig. 102), an introduced species first discovered in North America near Boston, Mass., in 1920 and in British Columbia during the same year, now occurs throughout most of New England and in the Maritime Provinces of eastern North America. In the West, it has spread southward through western Washington into northwestern Oregon. The larvae feed on most species of poplar and willow. Adults of both sexes are pure white with a satiny sheen and have a wingspread of 37 to 50 mm. The head, thorax, and abdomen are black but are so densely clothed with long, satiny-white hairs they appear white. Full-grown larvae are about 34 mm long. The head is black with a bluish tinge. The body is blackish on top with a row of large white blotches down the middle and a narrow broken line along each side. There is also a transverse row of reddish-brown tubercles on the top of each body segment, each bearing a tuft of yellowish-brown hairs.

Winter is spent in the larval stage. Feeding is resumed in April in New England. Young larvae feed only on the leaf surface, most often on the underside. Partly grown larvae eat small, irregular holes in the leaf, and full-grown larvae devour the entire leaf except the large veins. Feeding is completed by June. Pupation occurs in loosely woven cocoons of silk spun in the leaves or on twigs or other objects. Adults appear in late June and early July. Eggs are deposited on leaves, branches, and trunks of trees or on other surfaces in masses of 100 to 400. Each mass is oval, about 9 mm long, and covered with a glistening white secretion. Hatching occurs in about 2 weeks. Newly hatched larvae feed for 5 to 6 days and then spin small webs in which they molt to the second instar. These larvae then feed again for 5 to 6 days. Then they crawl to limbs or the trunk and spin hibernacula in bark crevices or under loose bark where they remain until the following spring *(174)*.

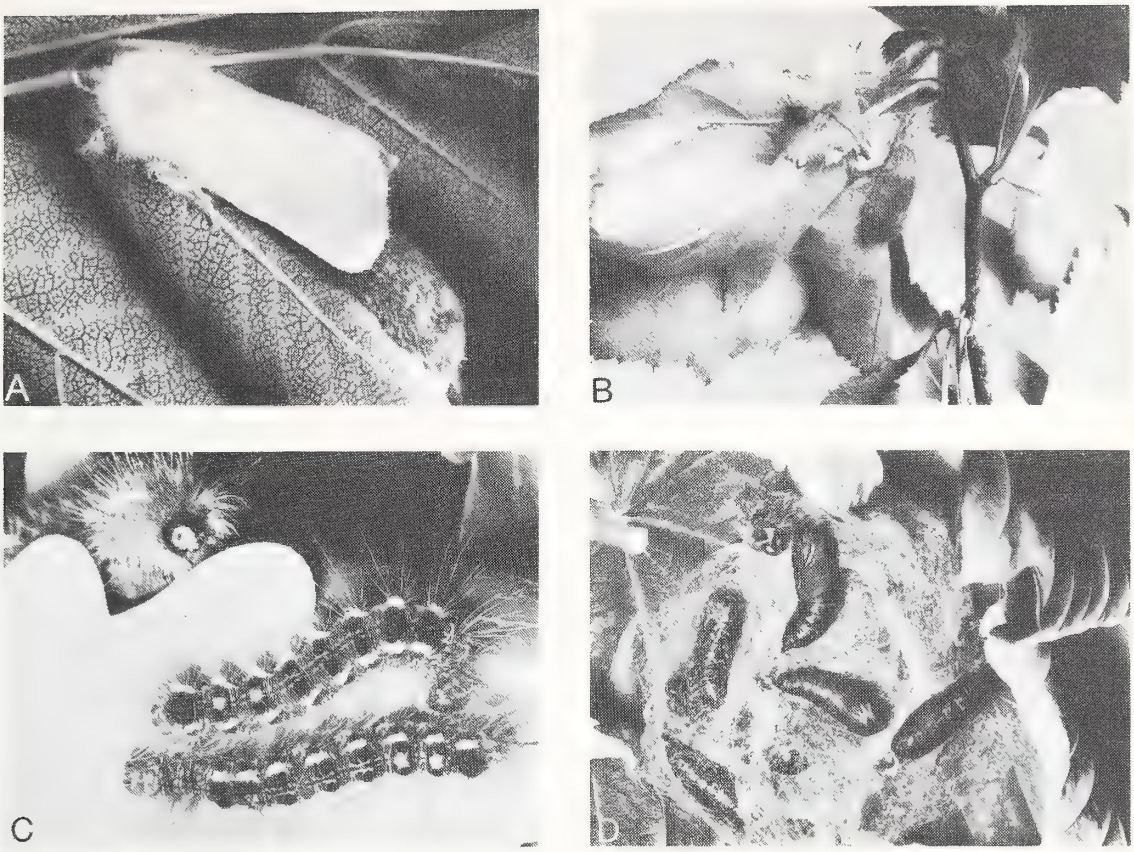
The satin moth is not very important as a forest insect in the Eastern States, although heavy infestations are occasionally reported. From time to time, it seriously defoliates poplars in ornamental plantings. A number of natural enemies (dipterous and hymenopterous parasites, fungi, insect and vertebrate predators) cause mortality of eggs, larvae, pupae, and adults *(328, 1236)*.

The **browntail moth**, *Euproctis chrysorrhoea* (L.) (fig. 103), an introduced species, was first recorded in North America in Somerville, Mass., in 1897. During the next few years, it increased enormously and spread rapidly. By 1905, it was extremely abundant throughout Rhode Island, eastern Massachusetts, southern New Hampshire, and southwestern Maine, and had been recorded as far north as New Brunswick and Nova Scotia. Ten years later, most of the area east of the Connecticut River, with the exception of northern New Hampshire and Maine, was heavily infested. Infestations also occurred in Vermont and west of the Connecticut

A, B, and D courtesy of L. Nef, For. Biol. Res. Cent., Genck, Belgium; C courtesy of Can. For. Serv., Marit. For. Res. Cent.

Figure 102.—The satin moth, *Leucoma salicis*: A, mating pair; B, hibernating webs on bark opened to show overwintering second instars; C, mature larva on aspen leaf; D, pupae (females are larger than males).

River in Massachusetts and Connecticut. Since then, the area and intensity of infestations have declined greatly. At present, infestations occur almost entirely in old, abandoned apple orchards and on beach plum on Cape Cod and in coastal counties in Maine. During the first several years following its introduction, its hosts were recorded as several species of deciduous trees, principally apple, pear, plum, oak, willow, elm, and maple.



A courtesy of Ziegler; B, C, and D courtesy of Shröder; Landwirtschaftskammer, Rheinland.

Figure 103.—The browntail moth, *Euproctis chrysorrhoea*: A, female ovipositing; B, egg mass on leaves; C, larvae; D, silken cocoons opened to show pupae.

Browntail moth adults are pure white except for the tip of the abdomen, which is covered with brown hairs. The female is rather heavy-bodied and has a wingspread of about 37 mm. Males are more slender and somewhat smaller. Full-grown larvae are about 37 mm long. The head is light brown; the body is dark brown to almost black with a broken white line on either side and two conspicuous red spots near the posterior end. There are also numerous tubercles with long, barbed hairs and many short, brown hairs on the dorsum and sides. These urticating hairs are allergenic to humans and cause a severe rash when they come in contact with skin.

Adults appear in early July, and the female deposits her eggs in elongate oval masses from 12 to 18 mm long on the undersides of leaves. Each mass contains about 300 eggs and is covered with brown hairs from the female's abdomen. Young larvae feed gregariously on the surface of the leaves. Later, they tie two or more leaves together with silk near the tip of a branch. Then they spin a web over the outside of these leaves and fasten them securely to the twig, thereby forming a tough, grayish web from 5 to 15 cm long where they spend the winter. Feeding is resumed in the spring, and the larvae become full grown by mid-June. Pupation occurs in silken cocoons spun usually among the leaves at the tips of twigs.

The browntail moth, although one of the better known forest and shade tree insects in the Eastern United States, is no longer of economic importance. For some undetermined reason, it has almost disappeared. Introduced parasites, many of which became established *(328)*, and a fungus disease probably helped toward its control, but it seems unlikely that they were primarily responsible for its decline.

Family Noctuidae
Owlet Moths and Underwings

This is the largest of all the families of Lepidoptera in North America. There are more than 2,900 species in the Noctuidae in North America. The adults are mostly nocturnal; many of the moths attracted to lights at night belong to this group. The larvae are usually dull colored and naked. Many are foliage feeders, some are borers, and others gnaw in fruits. Others are found on the foliage of forest and shade trees and shrubs, but they usually do not cause serious damage. A number of species attack seedlings in nurseries and young trees in plantations, and occasionally cause serious injury. This family has received extensive treatment *(268, 435, 684, 1002, 1032, 1108)*.

The genus *Acronicta* contains upwards of 100 species, many of which feed on the foliage of forest and shade trees. Some are known as "dagger moths" because of the presence of a daggerlike mark near the anal angle of the forewing.

The **American dagger moth**, *A. americana* (Harris), occurs throughout the Eastern United States and from Newfoundland to Alberta, Canada. Its hosts include a wide variety of hardwoods such as boxelder, basswood, red and sugar maples, paper and yellow birches, elm, ash, oak, willow, hickory, and sycamore. Full-grown larvae are about 50 mm long. They are clothed with fine, yellowish hairs and there are long, black hair pencils on the backs of abdominal segments one, three, and eight. Larvae are present from June to October, and overwinter in the pupal stage in dense silken cocoons. During an outbreak in Maine, larvae were so abundant that they literally swarmed all over buildings and gardens.

The **cottonwood dagger moth**, *A. lepusculina* Guenée, occurs from coast to coast in southern Canada and the Northern States. Its favorite hosts appear to be willow and quaking aspen, but it also occasionally infests other species of poplar. Full-grown larvae are clothed with long, soft, yellowish hairs and are about 37 mm long. There are single, long, black hair pencils on the backs of abdominal segments one, three, four, five, and eight. Larvae are present from July to October. Winter is spent in a cocoon composed of silk and bits of wood.

Many other species of *Acronicta* are also found on trees in eastern forests. Some of these with some of their more common tree hosts are as follows: *A. innotata* Guenée—hickory and birch; *A. morula* Grote & Robinson, the **elm dagger moth**—elm and basswood; *A. interrupta* Guenée—elm, cherry, birch, and apple; *A. lithospila* Grote—hickory and oak; *A. funeralis* Grote & Robinson, the **paddle caterpillar**—hickory, elm, and birch; *A. modica* Walker—oak; *A. retardata* (Walker)—maple; *A. leporina* (L.), the **poplar dagger moth**—poplar, willow, and birch; *A. distans* (Grote)—birch, cherry, poplar, willow, apple, and alder; and the **smeared dagger moth**, *A. oblinita* (J. E. Smith)—usually herbaceous vegetation but also occasionally poplar, willow, boxelder, pin cherry, alder, and apple.

The genus *Catocala* contains many large, conspicuous species, the larvae of which feed on the foliage of various forest trees and shrubs. As a group, they are of little economic importance. The forewings are usually grayish and mottled with lighter and darker spots. This makes them very inconspicuous on the trunks of trees when they are resting with their wings folded. The hindwings, in contrast, are beautifully marked with bright red, yellow, white, or brown. This has given rise to the common name "underwing moths." More than 50 species have been recorded from New York State alone, mostly on oak and hickory. The life histories of many species have been discussed *(56, 1055)*.

Many other species of noctuids are commonly known as "cutworms." The larvae are usually stout, naked, and dull grayish or brownish. They are seldom seen, however, because of their habit of feeding at night and hiding on the ground or under bark during the daytime. A number of species feed on the roots, or on portions of stems or foliage near the ground; many others climb the stems or trunks of their hosts and feed on buds, flowers, fruit, and other succulent parts.

The more important species of cutworms in nurseries and forests in eastern America and some of their hosts are as follows: *Feralia jocosa* (Guenée), the **joker**—hemlock, spruce, larch; *Idia aemula* (Hübner), the **spruce epizeuxis**—spruce (particularly in ornamental plantings; the larvae commonly are found in webbed masses of dried needles and frass on the branches); *Panthea furcilla* (Packard), the **tufted white pine caterpillar**—pines, *P. acronyctoides* (Walker), the **tufted spruce caterpillar**—spruce; *Papaipema furcata* (Smith)—ash seedlings in nurseries in the Lake States; *Colocasia propinquilinea* (Grote)—birch, beech, maple, walnut; *C. flavicornis* (Smith)—hickory; *Charadra deridens* (Guenée)—oak, maple, elm, birch; *Raphia frater* Grote, the **yellow-marked caterpillar**—poplar, willow; *Euxoa scandens* (Riley), the **white cutworm**—young white and overcup oaks (serious defoliation reported in Minnesota); the **zebra caterpillar**, *Melanchra picta* (Harris)—usually most abundant on herbaceous vegetation, but occasionally damages pine seedlings in nurseries in the northern Great Plains; *Orthosia hibisci* (Guenée)—the opening buds and fruit of many deciduous trees and shrubs and a few conifers; *Lithophane laticinerea* Grote—many species of deciduous trees (severe defoliation of red maples on islands in Penobscot River, Maine); the **green fruitworm**, *L. antennata* (Walker)—ash, boxelder (has occured in larger numbers locally in New York and Vermont); *Anomogyna elimata* (Guenée), the **chameleon caterpillar**—various conifers, especially balsam fir and jack pine (one of the most common of the cutworm larvae on conifers in the Northeast); and *Palthis angulalis* (Hübner), the **spruce harlequin**—a wide variety of conifers, especially balsam fir and white spruce, also occasionally on various deciduous trees.

Clean cultivation is recommended for preventing the development of damaging populations of cutworms in forest nurseries.

Order Coleoptera—*Beetles*

The order Coleoptera contains more named insects than any other; in fact, over a fourth of the named animals are beetles. The estimated number of named beetle species is about 350,000 *(27)*, and about 1,000 new species are named each year. Over 26,000 species occur in the United States *(980)*. Beetles can be distinguished from all other insects, except earwigs, by their hard and horny or leathery forewings that meet in a straight line along the middle of the back. The forewings, or elytra, cover the membranous hindwings used for flying; some species are flightless and lack hindwings.

All beetles have chewing mouth parts and complete metamorphosis, i.e., eggs hatch to produce larvae that feed to maturity; then the larvae transform to inactive, nonfeeding pupae which become adults that mate and lay eggs to repeat the life cycle. The life cycle varies greatly in length, from 10 or more generations per year to 1 generation in many years. For most beetles the larval stage is long and the egg, pupal, and adult stages are of short duration.

Beetle larvae and adults have a wide range of habits. The majority of the beetles are terrestrial but some species, even entire families, are aquatic both as larvae and as adults. Some feed on vegetable matter; others feed on animal matter. Many are phytophagous, many are predacious, some are scavengers, some feed on mold and fungi, and a few are parasitic. Beetles that feed on plants are of primary interest.

The order Coleoptera contains many of the most destructive forest insects. Adults and larvae of the phytophagous species have certain modifications in form and habits that enable them to feed on different portions of plants. A beetle species may cause damage to tree flowers, fruits, and seeds; roots, stems, or foliage of living trees; dead or dying trees; drying logs and lumber; or wood products many years after wood is placed into use. Considering the invaluable resources provided by forests—wood and wood products, clean air and water, recreation and wildlife as well as esthetic wilderness values—humanity is inadequately appreciative of the fact that parasites and predators help to limit the damage beetles might cause in most situations.

Beetles annually cause enormous losses to valuable timber or shade trees; to forest products by degradation, often through the introduction of blue-stain fungi or other pathogens; to seedlings in nurseries, plantations, seed orchards, or natural stands by growth loss or mortality; and to seed orchards by reducing harvest of viable seed. Most of the destruction results from feeding by larvae. Characteristically, initial attack by adults of many species is restricted to wood that is in a certain condition—either living, recently dead or dying, or decaying. Larvae of the Cerambycidae, Buprestidae, and some other families may continue to survive within wood that is too dry for initial attack. Some other beetles, e.g., the Lyctidae and some of the Anobiidae, are capable of repeatedly infesting seasoned wood in storage or service.

Identification.—Adult beetles in many families feed as defoliators or predators, but the most serious damage to forests and forest products results during the extended feeding period of the larvae of most families. Frequently the adults are short-lived or nocturnal and the feeding larvae are hidden, either beneath bark or deeply within the wood, and not readily available for identification. Although larvae are found more often than adults, specific or generic identification of larvae is often a difficult task, even for a taxonomic specialist. The family, group, and sometimes even the species can often be quickly and easily identified from careful attention to the general appearance of larvae and to what is being damaged, i.e., seeds, twigs, bark, wood of living, dying, or dead trees, logs, and wood products, etc.

Beetle larvae from various families can be grouped by general appearance according to their body form or shape. For a few families, larvae have a different body form with each molt. Larvae characterized by the absence of legs on the thorax are the weevil or curculionid type. They have thick crescent-shaped bodies and a well-developed head (families Curculionidae, Scolytidae, and late-stage Bruchidae). Larvae with thoracic legs are either very active with flattened bodies (thysanuriform) or slow moving with thick caterpillarlike bodies (eruciform). The thysanuriform type is further subdivided into the caraboid and triunguloid types. The caraboid type larvae have strongly developed mandibles and are mostly predacious (families Carabidae, Cicindelidae, Cleridae, Staphylinidae, Histeridae, etc.). The first instars of the Meloidae and Rhipiphoridae are about the only triunguloid examples.

Many wood-infesting beetle larvae are eruciform, but again there is a subdivision. Larvae of the scarabaeoid subtype are typical grubs with wrinkled, crescent-shaped, and often hairy bodies (families Scarabaeidae, Lucanidae, Anobiidae, Bostrichidae, and Lyctidae). Larvae of the cerambycoid subtype have straight rather than crescent-shaped bodies and are more active than larvae of the scarabaeoid subtype. The larvae of the Buprestidae have somewhat flattened bodies, but Cerambycidae and Elateridae larvae typically have rounded bodies.

There are extensive references to the taxonomy of coleopteran adults *(27, 128, 145, 635, 723, 724, 725)* and larvae *(1, 142, 243, 980)*. Keys to identification and descriptions of habits of species occurring in eastern North America are available *(304)*. Extensive checklists and manuals of the major families of beetles are being prepared by the North American Beetle Fauna Project of the Beetle Research Institute of America *(27)*.

The families described here are discussed in phylogenetic order from primitive to advanced. Some families do not contain forest-destroying insects but are included because they contain beetles frequently encountered in the forest.

Family Carabidae
Ground Beetles

The Carabidae, one of the largest families of beetles, contains hundreds of species. Both as adults and as larvae, nearly all ground beetles are predacious on other insects. Adults of most species are black or dull brown, but adults of a few species are yellow and may be marked with black. Some species are brightly colored, either metallic blue, green, or purple. Many have an orange prothorax or orange markings on the elytra. Size also varies greatly among species, but the body is flat to oval in cross section. Adults are unusually long lived—1 to 4 years—and are active even in winter. Ground beetles occur, sometimes abundantly, in most habitats, e.g., under stones, logs, forest litter, bark, or running about on the ground or branches.

Larvae are elongate, fusiform, and usually active. The integument is darkly sclerotized in the free-living species, but it is white in those species living in the ground or bark. The larvae have five-jointed legs, frequently with spines and single or paired movable claws on the fifth joint for grasping prey. Their mandibles are sickle-shaped for the same purpose.

Many carabids are very beneficial, preying on many of the forest pests that cause much damage. The prey include lepidopterous and hymenopterous defoliating pests, such as the gypsy moth and sawflies, and the immature stages of bark beetles. A number of species in the genus *Calosoma* are important predators of tree-defoliating pests and other insects. Adults are large, about 20 to 30 mm long, and some are brilliantly colored. Like many other carabids, these conspicuous predators emit a disagreeable odor when handled or disturbed.

A species introduced from Europe in 1906, *Calosoma sycophanta* (L.), is now widespread and well established over most of the area infested by gypsy moths and even beyond. Adults have a bluish-black pronotum with golden-green elytra, and they are from 24 to 30 mm long (fig. 104). Both the adults and larvae readily climb trees and feed voraciously on gypsy moth larvae and pupae. Many other insects are also preyed upon. Adults live up to 4 years, overwinter and lay eggs in the ground, and emerge about June. After climbing trees to feed to maturity, larvae return to the ground to pupate. The effectiveness of this predator has been investigated *(188)*.

Native species widely distributed in the Eastern States include *C. frigidum* Kirby (fig. 105), *C. willcoxi* LeConte, *C. scrutator* (F.), and the **fiery hunter**, *C. calidum* (F.) (fig. 106).

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Figure 104.—Adult of *Calosoma sycophanta*.

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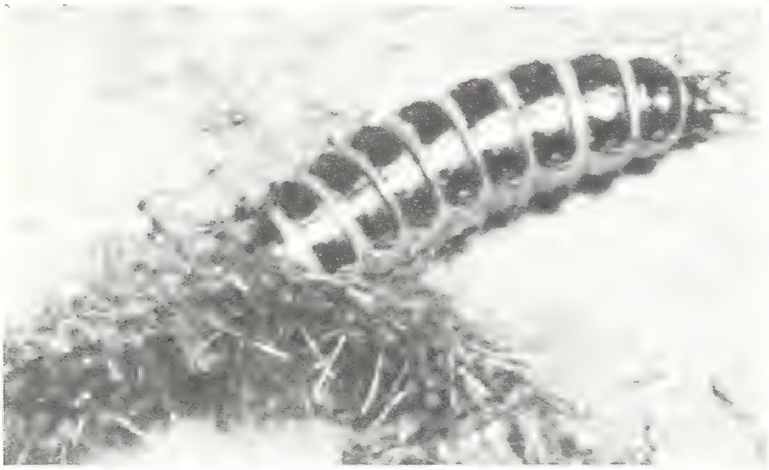
Figure 105.—*Calosoma frigidum* on a red maple twig in the field.



Courtesy Conn. Agric. Exp. Stn.

Figure 106.—Larva of the fiery hunter, *Calosoma calidum*, feeding on a gypsy moth larva.

Carabids frequently occurring in bark beetle galleries include *Mioptachys* and *Tachyta* spp. Several species, *Geopinus incrassatus* (Dejean), *Harpalus* spp., and *Scarites subterraneus* F., reportedly cause feeding injuries to tree seedlings; however, members of the latter genus are strictly predacious *(304)*.

Family Cicindelidae
Tiger Beetles

Tiger beetles are not forest pests but their appearance and habits arouse interest and curiosity. Both adults and larvae are predacious on other insects. Most species encountered will probably be in the largest genus *Cicindela*. Unlike other tiger beetles, most members are active in the daytime. Adults of *Cicindela* spp. are 9 to 18 mm long; they are mostly metallic green or bluish gray with yellowish to whitish bands or spots on the elytra. They are strong flyers and most often are seen swiftly

running along sandy stream banks or along woodland trails on bright, sunny days from early spring to fall. They will often stop, turn, and assume an aggressive posture toward intruders. This habit and the way they pounce on their prey has led to their common name. In striking contrast to the active adults, the larvae wait for prey to fall into conical, vertical burrows in soil.

Family Cupedidae
Cupedids

Beetles in this family are not of economic importance. Both adults and larvae occur in moist, badly decayed wood or under bark. *Cupes concolor* Westwood is a common, widely distributed species, sometimes found in structures of pine or oak. Adults have flattened bodies, 7 to 11 mm long. They are grayish brown and densely covered with scales. The larvae have a peculiar elongate, fleshy appearance and are 25 mm long. Each fleshy five-jointed leg is armed with a movable claw, a characteristic common to predacious forms. These are considered to be the most primitive of all beetles.

Family Silphidae
Carrion Beetles

Carrion beetles are often seen on animal excrement or around the bodies of dead animals in the forest. Many of the more commonly observed species are in the largest genera, *Silpha* and *Nicrophorus*. Adults of various species range from 10 to 35 mm in length. Their black bodies are often ornamented with yellow or red on the prothorax or elytra. Their bodies are soft and robust, usually elongated but sometimes circular. Several of the species of small size, like *Agathidium oniscoides* Palisot de Beauvois, apparently act as scavengers under the bark of logs and dead trees in galleries of bark beetle-infested hardwoods.

Family Histeridae
Hister Beetles

Hister beetles have widely varied habits and habitats. Adults as well as larvae are mostly carnivorous. Many are predacious on other adult insects and their larvae. Habitats include excrement, carrion, decaying fungi, fermenting sap, beneath bark, in ant and termite colonies, or in nests of small mammals and birds. Adults are generally small (2 to 10 mm), sluggish, hard-shelled, and often with shortened elytra. Most can feign death, drawing in their appendages when disturbed. The species with flat bodies live under bark, often of only certain tree species, apparently because they are predacious on a pest of the particular tree, e.g., *Hololepta* spp. under bark of poplar and yellow-poplar trees. The species with cylindrical bodies are found in galleries of bark beetles and wood borers, e.g., *Plegaderus* spp. prey on eggs and larvae.

Family Byrrhidae
Byrrhids

These beetles are oval, convex, and usually black, 1 to 10 mm long. The head is deflexed, retracted, and usually concealed from above. The hard-bodied, slow-moving adults retract their appendages when disturbed to form a compact ball and thus are referred to as pill beetles. Adults and larvae are herbivorous.

Although several species of the genus *Byrrhus* are abundant and cause much damage to tree seedlings, specimens are difficult to find because the adults are nocturnal. Adults are 5 to 10 mm long, black, and densely covered with grayish hairs. The distribution of this genus apparently is limited to Alaska, Canada, and the contiguous Northern States.

Family Staphylinidae
Rove Beetles

This very large family has over 300 genera, several of which contain numerous species. Rove beetles occur commonly in eastern forests on, in or near the forest floor, or under bark of dead trees. Many species are conspicuous and easily recognized, though the family is difficult to define. Adults are usually elongate, slender beetles, small to medium in size, and can run with considerable speed. The wing covers of nearly all species are decidedly shortened, exposing a long and slender abdomen. When disturbed, many of the larger species turn the tip of their abdomen up and over the body, as if threatening to sting, as they run away. Most species are uniformly black or brown, but many have red or yellow body segments interspersed among the somber colors. A large species often encountered, *Philonthus cyanipennis* F., is iridescent blue, purple, or green. Rove beetle larvae are highly variable, and several distinct types occur from soft, white larvae to heavily sclerotized, black larvae.

Most members of this family of beetles are predacious on insects or other similar soft-bodied small animals. A few species feed on fungi, a few on pollen, and some members of the genus *Aleochara* are known to be parasitic on fly pupae. Staphylinids are not economically important though many species occur in any given forest type. Common and conspicuous predacious genera that occur in a variety of forests are *Staphylinus* and *Philonthus*, which contain some of the largest members of this family. Other general predators are species of *Quedius*, *Tachyporus*, *Medon*, *Lathrobium*, and *Astenus*.

Members of at least 20 different genera in the eastern regions are known to be predacious on bark beetle eggs and first instars, and small wood borer larvae. Among those, the species of *Nudobius*, *Quedius*, *Phloeopora*, *Atrecus*, *Olisthaerus*, *Charhyphus*, *Placusa*, and *Phloeonomus* are common in eastern forests. Other genera contain species that can be predacious on insects under bark, such as *Tachinus*, *Sipalia*, *Leptacinus*, and *Homaeotarsus*. A few genera often occur in bark beetle galleries, but apparently do not feed on bark beetle eggs or larvae. Of these, members of the genus *Atheta* are common, and sometimes also *Siagonium*.

None of the staphylinid species is known to be a major factor in the control of any harmful forest pest. However, they are a consistent and abundant component of the complex forest ecosystems.

Family Passalidae
Passalid Beetles

These beetles are discussed because of their interesting appearance and biological habits. Most species occur in the tropics. Of the three species recorded from the United States, only the **horned passalus**, *Odontotaenius disjunctus* (Illiger), has a very wide distribution in the Eastern United States. Adults are large, somewhat flattened, parallel-sided, shiny black beetles from 30 to 40 mm long. The thorax and abdomen are separated with a narrowed "waist." The elytra are deeply grooved and a short, forward curved hook occurs on the top of the head. The three rigid, terminal antennal segments are widened into a loose club that cannot be rolled together.

Larvae and adults live together in colonies in damp, decayed logs and stumps. The cream or dull-white larvae are fed wood that has been reduced to a pulp and treated with digestive secretions by their parents *(499)*. Both adults and larvae have stridulatory organs. When disturbed, or for communication, adults rub together

roughened areas located on the underside of the wings and on top of the abdomen; on the larvae, these roughened areas are on the third pair of legs that are very greatly reduced.

Family Trogositidae
Trogositid Beetles

The family Trogositidae is made up of beetles formerly in the family Ostomidae. Species in several genera are important predators of some of the most destructive forest insects. These beetles are closely related to clerid beetles. Larvae of the two groups are very similar in appearance; however, most of the adults are different. Unlike the hairy bodies and contrasting colors of clerids, trogositid adults rarely have hairs and are entirely brown, blue, green, or black. Their bodies are usually flattened and elongate or oval. The terminal 3 segments of the 11-segmented antennae form a loose club.

Temnochila virescens (F.) is one of the most important insect predators of the southern pine beetle. Adults are iridescent, bluish green, and 10 to 18 mm long. They feed on bark beetle adults on the surface of infested wood, though not as actively as do the clerids. Larvae are elongate and cylindrical with a sclerotized plate bearing a pair of unbranched recurved hooks. They burrow through bark beetle galleries as they prey on eggs and larvae of the host.

Other predacious trogositids occurring in eastern forests and their insect hosts include: *Tenebroides corticalis* (Melsheimer)—bark beetles; *T. bimaculatus* (Melsheimer)—*Agrilus* larvae in oaks; *Corticotomus cylindricus* (LeConte) and *Airora cylindrica* (Serville)—ambrosia beetles and cossonid weevils.

Family Meloidae
Blister Beetles

Blister beetle adults are most commonly seen defoliating forest vegetation. Distinctive characteristics are: green, gray, brown, or black color; usually 8 to 18 mm long; slender, soft-textured, and usually elongated body and elytra; subcylindrical; head and elytra wider than pronotum; head narrowed abruptly into a neck; often large and swollen abdomen; long legs; and cleft tarsal claws each with a lower appendage. The larvae of the genus *Epicauta* prey on grasshopper eggs, all others being predators in nests of wild bees.

Species that defoliate seedlings in nurseries and ornamental plantings in the Midwest include: The **threestriped blister beetle**, *Epicauta lemniscata* (F.); the **margined blister beetle**, *E. pestifera* Werner; the **ashgray blister beetle**, *E. fabricii* (LeConte); *Lytta aenea* (Say); and **Say blister beetle**, *L. sayi* (LeConte). The **caragana blister beetle,** *E. subglabra* (Fall), the **Nuttall blister beetle,** *L. nuttalli* Say, and the ashgray blister beetle defoliate caragana in the Great Plains; *E. torsa* (LeConte) defoliates Kentucky coffeetree, honeylocust, and mimosa in Florida and Oklahoma. *L. polita* Say feeds on male strobili of shortleaf and pond pines in the South,consuming the pollen sacs of mature male flowers, leaving only the flower stalks or axes. The biology and control of seven common species are discussed *(602)* and plant host records of Meloidae associated with bees have been compiled *(385)*.

Family Nitidulidae
Sap Beetles

Sap beetles are usually oval, sometimes elongate and flattened, and 1.5 to 12 mm in length. They are usually black and often marked with red or yellow. Antennae are 11-segmented, with a variable shaped but always 3-segmented club. Elytra are usually short and truncated at the apices, exposing the tip of the abdomen. The larvae are nearly white, subcylindrical, moderately elongate, and usually 7 to 12

mm in length. Paired and forked horny projections are often found on the ninth abdominal segment. Keys to the species occurring in Delaware are available *(232)*.

Both adults and larvae of many species feed on decaying fruit, fermenting sap under bark, and sap exudations from freshly cut logs, stumps, or wounds on living trees. Bark-infesting species often kill patches of cambium (fig. 107) that heal over to form pocket defects causing lumber degrade losses in valuable species like oak. A number of species apparently can penetrate the bark of oak where there are no previous injuries. Numerous studies have shown that nitidulid beetles are vectors of oak wilt fungus, *Ceratocystis fagacearum* (Bretz) Hunt.

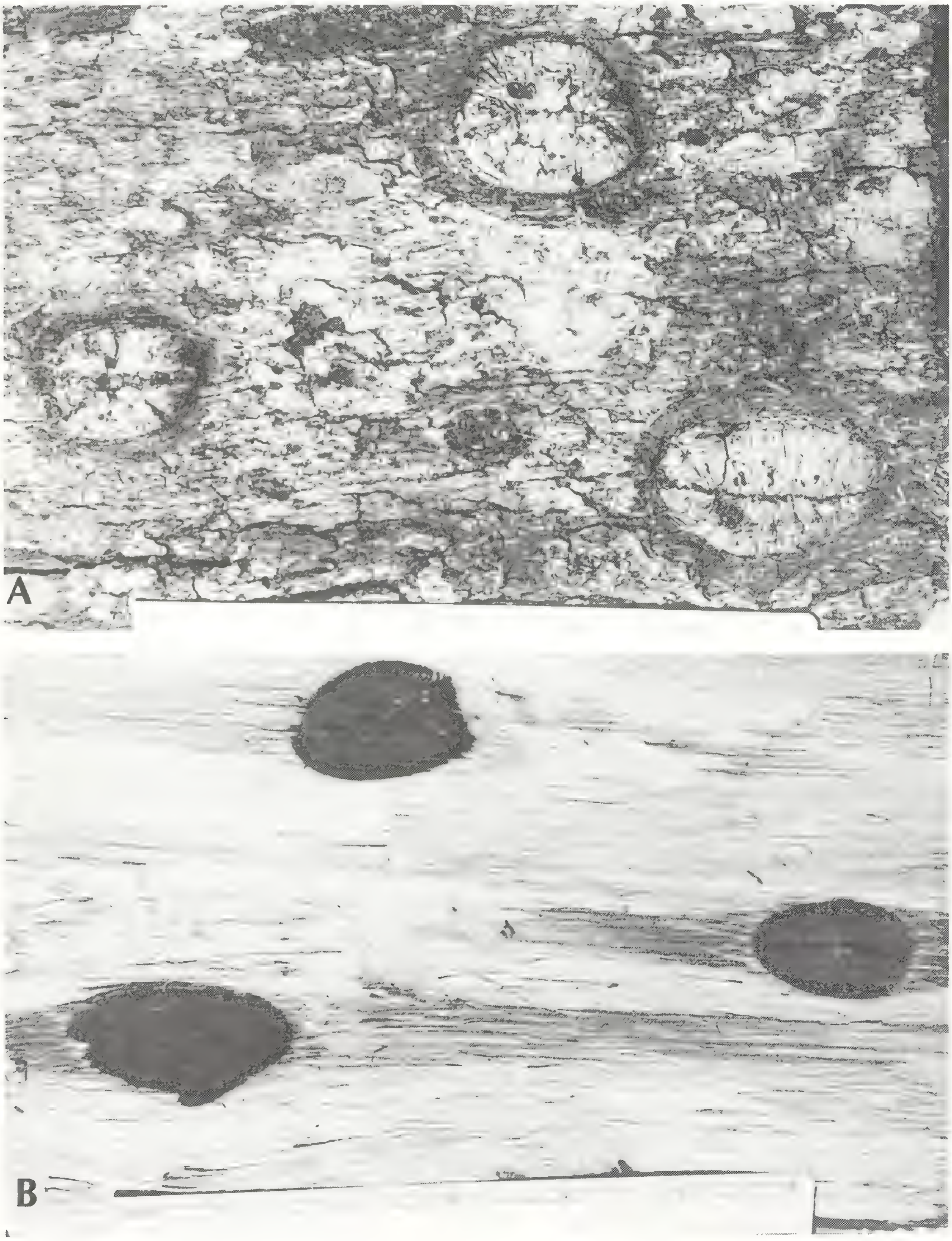


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Figure 107.—Evidence of nitidulid attacks on oak: A, scars overgrown after attacks; B, pockets in the wood beneath scars shown on A.

Family Coccinellidae
Lady Beetles

Lady beetles are small, usually less than 5 mm long. Their bodies are round, usually convex or hemispherical, and shiny, often marked with red, yellow, black, or white spots. The larvae have a large, protruding head with a fleshy, elongate, tapering body that is covered with tubercles or spines, and have well-developed, five-jointed legs. They are black or gray and are frequently marked with bright colors.

About 400 species occur in the United States. There are keys to the identification of species occurring in Minnesota *(1151)*. As a group, lady beetles are among the most beneficial and most widely recognized of all insects; one review covers 206 references on predacious species *(512)*. Both adults and larvae of most species are predacious on scales, aphids, and spider mites or on the eggs and larvae of larger insects. Both stages usually occur on the host plants of their prey, and eggs are laid in clusters on leaves or bark. Adults overwinter, sometimes in enormous congregations. However, species in the subfamily Epilachninae are herbivorous and some, such as the **Mexican bean beetle**, *Epilachna varivestis* Mulsant, are notorious pests of food plants. Some other species feed on spores of mildew or rust fungi. A few of the most important predators of forest insects will be discussed briefly.

An introduced species, the **twospotted lady beetle**, *Adalia bipunctata* (L.), is an important predator of pine needle, juniper, beech, and terrapin scales in the Northern States. Adults are 3 to 5 mm long. The head is black with two yellow spots between the eyes; the thorax is black with yellow margins; and the wing covers are red, each with a black central spot.

The **twicestabbed lady beetle**, *Chilocorus stigma* (Say), occurs in the Northern States and feeds commonly on pine needle, beech, terrapin, and juniper scales. The adult is 4 to 5 mm long, shiny black with a round red spot on the disk of each elytron. The venter of the abdominal segments is red.

The **convergent lady beetle**, *Hippodamia convergens* Guérin-Méneville, feeds on aphids and scales throughout most of the United States. Adults are 4 to 6 mm long. The pronotum is black except for pale margins and is marked with two discal bars; the elytra are reddish with a black scutellar spot and 12 more or less distinct black spots; and the venter and legs are black. In some parts of the country this species hibernates in clusters of tens of thousands. In very hot summers it aestivates in a similar manner.

Hyperaspis congressis Watson is widely distributed in the Eastern United States and is an important enemy of the pine tortoise scale. Adults are shiny black, strongly punctate, and 2.5 mm long. A rather large yellowish spot occurs on the middle of the elytra and often a fainter one is present on the wing tips. *Anatis mali* (Say), the **fifteen-spotted lady beetle**, feeds on a wide variety of forest insects, including young larvae of the gypsy moth and cankerworms, in the Eastern United States. Adults are yellowish and 8 to 10 mm long. There are two pale spots enclosed in a black disk on the thorax, a single spot on the scutellum, and seven black spots on each elytron.

Coccinella novemnotata Herbst, the **nine-spotted lady beetle**, is a common and widely distributed species that feeds on aphids and scales on both conifers and hardwoods. Adults are 5 to 7 mm long. The body is pale yellow, and black beneath. Each elytron bears four black spots, and one black spot is on the elytral suture.

The **transverse lady beetle**, *C. transversoguttata richardsoni* Brown, feeds on scale insects infesting pines in the more northern States. Adults are reddish, 6 to 7.5

mm long. The wing covers may be without spots or each one may be marked with a long, transverse subbasal spot, a shorter transverse spot near the middle, and a third near the tip.

Several species of coccinellids have been imported against the balsam woolly adelgid in recent years. The European species, *Aphidecta obliterata* (L.), initially became established in infested Fraser fir stands in North Carolina but its present fate is unknown *(396)*. Eggs are laid on the needles or trunks of infested trees, and the larvae and adults feed on all stages of the adelgid except the first instar. Attempts to establish this species in New Brunswick were unsuccessful *(163)*. *Scymnus (Pullus) impexus* Mulsant, one of the most important enemies of the adelgid in Central Europe, has been released in infested stands of fir in New England and North Carolina. The adults and larvae feed on second and third instars of the adelgid. It does not appear to be established *(396)*.

Other important species of native coccinellids include *S. lacustris* LeConte, an enemy of the pine tortoise scale in the Lake States; *Microwesia misella* (LeConte), a minute species less than 1 mm long that feeds on various species of scale insects; *Cleis picta* (Randall), which often occurs in large numbers on pines infested with the red pine scale in the Northeast; and the **spider mite destroyer**, *Stethorus punctum* Casey, which is the mainstay of integrated spider mite control in apple orchards in Pennsylvania.

Family Derodontidae
Derodontids

This little-known family contains about five species in the Eastern United States. Adults are brown or motley brown and are 2 to 6 mm long. Larvae and adults of some species occur together on or in slime molds and shelf fungi. These habitats and the sharp projections on the margin of the prothorax have led to the name "tooth-neck fungus beetles." Some native species are general, though not important, predators of adelgids on conifers.

Laricobius erichsonii Rosenhauer, a European predator of the balsam woolly adelgid, has been established in adelgid-infested stands of fir in Canada, New England, North Carolina, and the Pacific Northwest. It appears to be the only foreign predator of the adelgid established in North Carolina *(396)*. The adult is an elongate oval beetle, 2.2 to 2.4 mm long, with a deflexed head that is usually hidden from view dorsally. The body is covered with yellowish to brownish to black hairs; the central portions of the elytra, the antennae, and the legs are reddish brown. Adults deposit eggs within adelgid egg clusters or under lichens on the bark. The larvae, often covered with bits of adelgid's wool and bark, feed to maturity on adelgid eggs, drop to the ground, and pupate in cocoons of compacted soil particles *(164)*.

Family Cucujidae
Cucujid Beetles or Flat Bark Beetles

Adults of this family are yellow, red, brown, or black. They are extremely flattened since they are adapted to living under close-fitting bark of unhealthy trees or recently felled trees and logs. The larvae are depressed in shape. The majority are scavengers but a few are predacious on mites or insects.

Cucujus clavipes F. is conspicuously bright red, extremely flat, and 10 to 14 mm long. It is common in the Northern States, especially under bark of recently dead ash and poplar. *Catogenus rufus* (F.) larvae are usually found parasitizing the pupae of wood-boring Cerambycidae or larvae of Braconidae. The adults are reddish brown and are up to 12 mm long.

Family Colydiidae
Colydiids

Members of this family vary in form and habit. They are hard-bodied, shiny, often beautifully sculptured, and reddish brown to nearly black. Many species are elongate, cylindrical, and rarely more than 5 mm long, but some larger species are strongly flattened and oval. Larvae of the latter are more robust in form and usually are found as scavengers in bark beetle galleries. Larvae of other species—*Nematidium filiforme* LeConte, *Bitoma carinata* (LeConte), and *Colydium lineola* Say—are elongate, slender forms that prey on larvae of ambrosia beetles, cossonid weevils, and some other wood borers. Other species are phytophagous and live on fungi or decaying vegetation.

Family Melandryidae
Melandryids

Adults of this family are 2 to 15 mm in length, and they are usually elongate to oval, loosely jointed beetles. Their antennae are 11-segmented and filiform; their color is dark brown to black. Adults are seldom seen, but the larvae occur commonly under the bark on dry, decaying logs or in dry fungi.

Some of the more common species and places to expect them are: *Melandrya striata* Say—many different hardwoods in association with black lines of decay; *Orchesia castanea* Melsheimer—oak, maple, yellow-poplar, sycamore, and hickory; *Hypulus concolor* (LeConte)—rotting pine sapwood; *Serropalpus substriatus* Haldeman and *Eustrophus tomentosus* Say—various conifers; and *Dircaea quadrimaculata* (Say) and *Holostrophus bifasciatus* (Say)—various hardwoods.

Family Oedemeridae
Oedemerid Beetles

Adults are usually elongate and subcylindrical with elytra soft in texture and sometimes covered with fine silken hair. Their color varies from pale to black, often with red, yellow, or orange markings. They range in length from 5 to 20 mm. The next-to-last tarsal segment is dilated and bears a dense, hairy pad beneath. Not much is known of the habits or habitats of the 68 species in the United States. Adults commonly visit flowers to feed on nectar, sometimes pollen, and they are attracted to lights. The larvae feed in damp, decaying wood.

The **wharf borer**, *Nacerdes melanura* (L.), is cosmopolitan and occurs on most coastlines and around the Great Lakes *(331)*. Adults are reddish yellow with a dark patch on the head, two dark patches on the thorax, and blackened tips on the elytra. Larvae of this species, the only economically important member of the family, occasionally are very destructive to moist wood poles, pilings, boardwalks, or basement timbers *(885)*. Adults are present from April to July in outdoor infestations, but they may emerge at other times within buildings.

Family Tenebrionidae
Darkling Beetles

Many species of this large family occur in the forest. The adults are hard-shelled, usually dark brown or black, 3 to 20 mm in length. Many are clumsy and slow-moving. The larvae are long and slender, and are often covered with tough, horny skins. The majority of forest species feed as scavengers on dead vegetable matter and fungi. They are commonly found under the bark of dead and dying trees or decaying logs, and occasionally in the galleries of bark beetles. A few species in the genus *Strongylium* bore into the wood of living trees at stubs or wounds.

Family Lymexylonidae
Timber Beetles

Two species of timber beetles are known from the Eastern United States. Adults are slender and elongate; the head is deflexed and narrowed behind the large eyes to

form a neck. Larvae are also elongate and slender, with globular heads. They bore deeply into timbers, causing pinhole defects—small tunnels across the grain having dark, stained walls.

The **chestnut timberworm**, *Melittomma sericeum* (Harris), once a destructive pest of chestnut, is now found chiefly in white oak. The nocturnal adults are brown, clothed with fine silky hair, and are 11 to 15 mm long. Eggs are laid in cracks in the wood surface.

The **sapwood timberworm**, *Hylecoetus lugubris* Say, is a reddish-brown or blackish beetle 10 to 12 mm long. Eggs are laid from April to July on bark of dying trees or unseasoned logs. Larvae bore across the grain of the sapwood of various hardwoods, such as poplar, birch, yellow-poplar, basswood, buckeye, and black walnut. The larvae have a distinguishing feature, a conical, slender, barbed spine on the ninth segment.

Family Mordellidae
Tumbling Flower Beetles

Adults of this family can be recognized by their habit of jumping or tumbling off flowers and by their characteristic strongly arched, wedge-shaped bodies that usually end in a long, conical process. They are usually black or dark brown, often spotted or banded with yellow or silver, and from 3 to 7 mm long. The head is bent downward, and the hindlegs are long, flattened, and spiny. The larvae of many species feed in rotting wood; some species are reportedly predacious.

Beetles That Damage Seasoned Wood

Numerous beetle species may damage seasoned wood in storage or use. Beetle larvae bore meandering, powder-filled feeding tunnels within wood, and the adults chew small round or oval holes in the surface of wood as they emerge. Adults of a few species bore short tunnels into wood for egg laying. When heavily infested or repeatedly attacked over an extended period, wood is often reduced to a mass of powder surrounded by a thin shell of sound wood perforated with holes. Damage of this type has commonly been termed "powderpost."

Beetles that cause a powderpost type of damage to wood are, as a group, ignored and misunderstood by many entomologists, foresters, and wood users. Damage, superficially similar in appearance, may be caused by numerous species within the families Anobiidae, Lyctidae, Bostrichidae, Ptinidae, Curculionidae (subfamily Cossoninae), and a few species within the families Cerambycidae and Oedemeridae. Many of these beetles can reinfest wood after it is dry, although some require wood in a very moist condition (Oedemeridae, Cossoninae weevils, and Ptinidae) and with bark attached (most Bostrichidae).

Seasoned wood may also contain damage from various other beetles within the families Buprestidae, Cerambycidae, Platypodidae, and Scolytidae. Although adults initiate the attacks in the moist wood of trees recently dead or dying or in drying logs and lumber, larvae may complete their development in wood after it is dry. These beetles, but not necessarily their damage, are usually removed during wood processing; damage is frequently misidentified as that of beetles capable of reinfesting dry, seasoned wood. Occasionally, adults may emerge from air-dried wood after it is in use. Additionally, larvae of the families Dermestidae, Tenebrionidae, and nonwood feeding Anobiidae occasionally use wood as a pupation site.

Fortunately, the numerous beetles that damage seasoned wood may be identified to group by characteristics of habits and damage. The incidence and location of

damage are dependent on the habits and food requirements of the various beetles and on people's utilization of wood *(1299, 1302)*. Infested wood products result from susceptible wood being placed in favorable conditions for beetle attack. Some of the many beetles that can reinfest seasoned wood have less restrictive requirements than others. Therefore, some beetles occur in structures much more frequently than others, e.g., Anobiidae, Lyctidae, and Cerambycidae (old house borer, *Hylotrupes bajulus* (L.)) (fig. 108). These three groups of beetles can be distinguished easily by characteristics of damage. Group, not species, identification is necessary for the proper selection of control measures. Failure to make distinctive identifications, or failure to use distinctive common names may lead to inadequate or unnecessary control operations *(1300)*. Habit and damage characteristics are summarized for the beetles most frequently attacking seasoned wood (table 2). Many different beetles with different requirements may occur in the same situation. Therefore, key damage identification characteristics are given to distinguish infestations of beetles that cannot reinfest seasoned wood from those that can. In addition, guides for inspection of new and existing structures are available to aid wood users in damage identification by providing color illustrations of damage by various beetles, other insects, and decay organisms, and by giving the incidence of each organism both within structures and within the United States *(729, 730)*. For the most important beetles infesting seasoned wood, conditions affecting their attack and changes in wood processing and use that influence the likelihood of infestation are reviewed to suggest the outlook for prevention and control *(1302)*.

Family Anobiidae
Deathwatch and Drugstore Beetles

This family contains about 52 genera and 318 species in the United States. The common names "deathwatch beetles" and "drugstore beetles" are not useful terms. A more acceptable name would be "shield beetles" because of the way they shield themselves, as described below. Adults are of widely diverse sizes and colors,

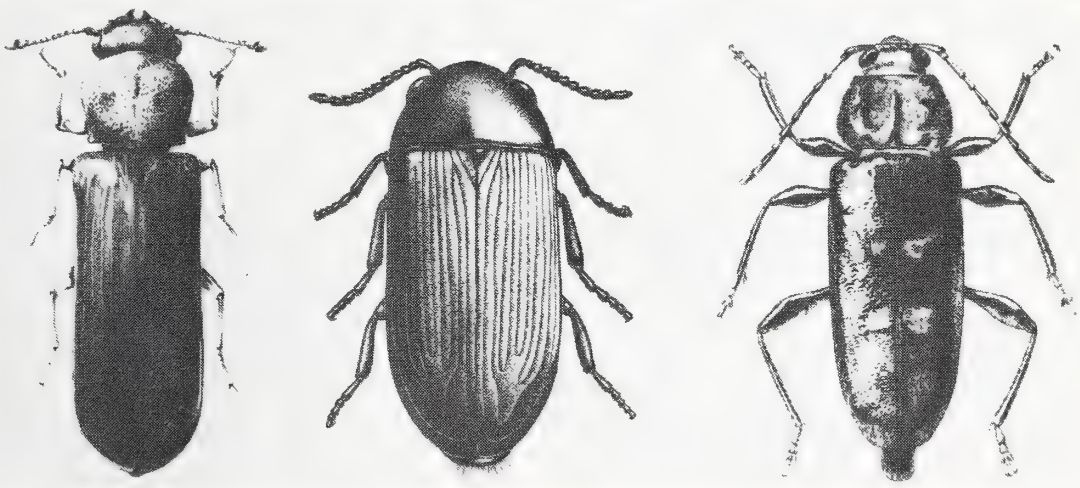

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Figure 108.—These are adults—seldom seen by the homeowner—of the three most destructive groups of wood-destroying beetles. Left: One of the *Lyctus*, or true powderpost beetles, which attack recently seasoned hardwood sapwood. Center: One of the anobiid beetles, which are among the most common feeders on both hardwoods and softwoods within buildings. Right: The old house borer, sometimes called a longhorn borer from its antennae, primarily attacks softwood framing lumber.

Table 2.—Typical damage identification characteristics and critical required conditions of beetle pests of seasoned wood

Beetle group	Type & age of wood damaged[1]	Type of product	Percentage wood moisture requirements	Critical requirements	Key damage characteristics	Length of life cycle	Other beetles[2]
Anobiid (Anobiidae)	Old softwoods and hardwoods	Wood exposed in crawl spaces & outbuildings, or as stored lumber. Also wood in living areas for widespread infestations	Probably 13-30	Moisture	Gritty frass, lemon- or bun-shaped pellets	1-5 yr or longer; usually 2-3 yr	Lycids—frass Ambrosia—tunnels have stained walls but no frass. Bostrichids or bark beetles—adult body shape, minor damage adjacent to bark of softwood
Lyctid (Lyctidae)	New hardwoods, frequently of tropical origin	Finish flooring, millwork moldings, occasionally furniture or plywood	6-30	Large pores, starch	Loosely packed frass feels like talcum powder	3 mo to 4 yr; usually 1 yr	Ambrosia beetles—(see above) Bostrichids—frass Anobiids—frass, age of product

continued

Table 2.—Typical damage identification characteristics and critical required conditions of beetle pests of seasoned wood (continued)

Bostrichid (Bostrichidae)	New hardwoods, rarely softwood by a few species	Same as lyctids plus firewood, softwood structural timbers	6-30	Starch, native species require bark and 30% moisture for attack	Coarse, tightly packed frass	1 yr usually	Lyctids—frass Anobiids—frass, age of product
Old house borer (Cerambycidae)	New softwoods only	Structural timbers, lumber	10-13 at least	Moisture, nitrogen	6 mm oval holes; coarse, tightly packed frass	3-10 yr	Miscellaneous Cerambycids—stringy tobaccolike frass Buprestids—tunnel height ⅓ width
Weevils (Curculionidae)	Old softwoods and hardwoods	Wood in contact with ground	Very high	Moisture	Holes similar to anobiids, no pellets	1 yr probably	A rare pest

[1] Old—10 or more years elapsed since processing.
[2] Key characteristics distinguishing damage of other beetles that may most commonly occur in same situation.

ranging from 1.5 to 8 mm and from bright reddish-brown with orange patches on the wing tips to a shiny ebony black. Adults of many species appear yellowish or grayish from the dense pubescence covering their bodies. To varying degrees, all species share common characteristics of a hoodlike pronotum that conceals the head when viewed from above, convex body shape, and the contractile ability to shield their appendages by retraction. Many genera and species can retract their appendages into specialized grooves when at rest; thus, they resemble the seeds of their host plant.

Members of this family have widely diverse habits, food hosts, and habitats. Anobiid beetles occur in most forest habitats, but many are not well known or frequently collected. Apparently, no species causes damage of economic significance to living plant material although many species in the genus *Ernobius* are frequent secondary invaders of aborted pine cones. Many species smaller in size feed on puffballs and other fungi or on plant seeds, but the majority of the larger species have wood-infesting habits. Many feed on dead twigs and branches or aborted cones, others in or beneath the bark of decadent trees. Many other species require bark-free dead wood such as branch stubs, lightning scars, or fallen trees. These species perform a function similar to that of subterranean termites and help reduce dead wood to nutrients for new plant growth. Some species with this function are restricted to wood of deciduous trees, others to only coniferous wood, and still others can attack wood of both types. Some of the species that attack seasoned wood have become frequent pests of wood in fabricated structures, especially when conditions surrounding the wood are favorable to their development.

Two nonwood-feeding species have become so adapted to human activities that they are now cosmopolitan pests of stored products. These are the **drugstore beetle**, *Stegobium paniceum* (L.), and the **cigarette beetle**, *Lasioderma serricorne* (F.), and they will feed in a wide variety of products including cereal grains, spices, tobacco, etc. Occasionally, they will excavate wood near food products when pupating, thus suggesting that they originally had wood-infesting habits.

Only a few species that most commonly damage seasoned wood in storage or use will be discussed. Adults of most species attacking seasoned wood are reddish brown to brownish black and range from 2.8 to 7.5 mm in length. With the exception of a few species, eggs are usually laid on the wood surface in cracks or crevices or in the holes made by emerging adults. The larvae are whitish with yellowish-brown heads, grublike, and may be 10 mm in length at maturity. The size of the adults and their exit holes are variable within a species. Exit holes are circular, typically 3 to 4 mm in diameter. The duration of the life cycle varies with the temperature and relative humidity conditions surrounding the wood as well as with its nutritive content. The cycle may require 1 to 5 years or more.

Many of the wood-infesting species can be identified with keys *(1283, 1285)*. *Xyletinus peltatus* (Harris) is the most widely distributed species in the Eastern United States, with a range from southern Canada to Texas to Florida. *X. peltatus* is probably the most common species infesting structures in the southern half of its range *(869, 1142, 1308)* and the third most common species in the northern half *(1086)*. Adult beetles are seldom seen because they are nocturnal and may live for only a few weeks. On the Mississippi Gulf Coast, adult emergence may begin in mid-April, peak in late May or early June, and continue through September, but 80 to 90 percent of the adults emerge within a 4- to 6-week period surrounding the peak of emergence *(1309)*. These beetles cause the greatest damage in the warm,

humid areas of their range. Nevertheless, infestations usually occur only when unfinished, untreated wood is exposed in a humid environment such as improperly stored lumber, in crawl spaces of buildings, or in outbuildings *(1298, 1299)*.

Damage may occur to heartwood if sapwood is attacked, but usually only the sapwood is damaged. Wood from both coniferous (softwood) and deciduous (hardwood) trees are attacked; in fact, yellow-poplar sapwood has proved to be a preferred species for egg laying, and best for larval growth and survival over seven other woods tested *(1306, 1307)*. Most structural infestations originate in softwoods that are exposed in crawl spaces (fig. 109), as softwoods are most commonly used for building construction. With time and favorable conditions, infestations may spread upward to the hardwood flooring, molding, and furniture. Populations within infestations increase slowly, and wood has usually been in service 10 or more years before attacks are discovered *(1304, 1308)*. Several factors explain this: (1) relatively few eggs are laid per female, (2) the life cycle is usually at least 2 years in favorable woods and may be 3 to 5 years in unfavorable woods, and (3) damage is not easily detected until adults emerge and make holes on the exterior surface. These factors just discussed, larval feeding primarily in springwood layers of softwoods *(1301)*, and load sharing capacities of complete floor systems indicate that control of infestations in crawl spaces can be achieved after attack and before structural weakening occurs if done before infestations spread upward *(1303)*.

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Figure 109.—Damage to softwood lumber in crawl space of a house. Note the piles of frass as the result of feeding by anobiid powderpost beetle larvae.

Hemicoelus carinatus (Say) is the most common species in structures in the Northeastern United States *(1086)*. Its distribution is from Maine to Manitoba southward to Kansas and eastward to North Carolina. Both hardwoods and softwoods are attacked, with the preponderance of attacks paralleling the prevalence of hardwoods in the region. Host woods include: silver and sugar maples, yellow and paper birches, white and northern red oaks, white ash, American beech, and American basswood *(1084)*. The frass is loosely packed within tunnels and will fall out when damaged wood is gently tapped. The frass contains elongated pellets *(1087)*.

Common predators and parasites associated with *H. carinatus* include: *Pelecotoma flavipes* Melsheimer (Coleoptera: Rhipiphoridae), *Heterospilus flavicollis* (Ashmead), and *Histeromerus canadensis* Ashmead (Hymenoptera: Braconidae).

Ptilinus ruficornis Say is the second most common species in structures in the Northeast *(1086)*, but is the most common species in northeastern hardwood forests *(3)*. This species attacks only hardwoods, and this habit may possibly explain why it is found in forests more than in structures. Its distribution is from Newfoundland to Alberta and extends southward to Kansas, southeastward to Alabama, and northeastward to Virginia. Host woods include the same hardwood species given for *H. carinatus* except the oaks and ash *(1084)*. *P. ruficornis* females bore short tunnels into bark-free wood for egg laying. Apparently, females have a mating or aggregating pheromone *(3)*. Unlike other anobiids, the frass is very tightly packed in larval tunnels and does not contain discrete pellets.

Other native and introduced species may occasionally be found damaging wood in use. Their occurrence in structures is of academic rather than practical significance because species identification is not needed for controlling infestations. Descriptions and distributions of these species are available *(1086, 1283, 1284)*. Additional information *(3)* is available for the native species which include: *Platybregmus canadensis* Fisher, the **Canadian powderpost beetle**; *Priobium sericeum* (Say); *Oligomerus obtusus* LeConte; *O. alternans* LeConte; and *Xyletinus harrisii* Fall.

A number of species have been introduced that are well-known wood-destroying pests in other parts of the world: *Nicobium hirtum* Illiger *(1123)*; the **furniture beetle**, *Anobium punctatum* (De Geer) *(132, 567, 740)*; *Xestobium rufovillosum* (De Geer), the **deathwatch beetle** (*132, 567*); and *Ptilinus pectinicornis* (L.) *(1085)*. Although these species have been reported from various locations, probably only the first species has a very wide distribution.

Many anobiid beetle species can infest only dead wood in branch stubs or lightning scars of living trees. Various species within the genus *Ernobius* commonly occur in bark, dead twigs, or aborted cones on coniferous trees. *E. mollis* (L.), an introduced species, has been reported from southeastern Canada southward to Florida and Texas. The larvae feed under the bark but may bore into the wood where the bark is thin or when infested wood with bark is used. Thus, adults may emerge from wood in structures but they cannot reinfest dry wood. Bark-beetle weakened trees are particularly susceptible to attack. *E. granulatus* LeConte, *E. tenuicornis* LeConte, and *E. filicornis* LeConte are other species of rather widespread but not well-known distribution. Adults of these *Ernobius* species are yellowish to reddish brown to brownish black and they have a similar range in size of 2.3 to 4.3 mm. More specific descriptions are available *(1283, 1284)*. Their hosts are not well known.

Many other anobiids are apparently indigenous to hardwood forests and reported only from hardwood hosts *(3, 1283)*. Many of the species are in the genus *Petalium* *(437)*.

Petalium bistriatum (Say) occurs from Massachusetts and New York to Ohio and south to the Gulf of Mexico. It breeds in the twigs of various hardwoods such as oak, dogwood, walnut, and buckeye *(74)*. Adults are 1.8 to 3.0 mm long; the head, pronotum, and undersurfaces are reddish black to black, the elytra black, the legs reddish, and the antennae yellow. *P. seriatum* Fall has been observed breeding in the dead twigs of pine, oak, and bittersweet. Adults are reddish brown to nearly black and are 1.5 to 2.5 mm long.

Hadrobregmus notatus (Say) occurs in southeastern Canada and southward to North Carolina and Mississippi. It has been recorded feeding in dead oak branches in Ohio. Adults are dark reddish-brown and 3.2 to 4.3 mm long. *Eucrada humeralis* (Melsheimer) larvae feed beneath the bark of dead oak and beech trees. It occurs from Quebec to Michigan in the North and southwestward and southeastward to Iowa and South Carolina.

Many of the smaller anobiid species within the genera—*Caenocara, Dorcatoma*, and *Tricorynus*—feed on various plant seeds and fungi. Some species have been reported attacking stored pine cones or small tree branches.

Family Lyctidae
Powderpost Beetles

This family contains 12 genera and more than 60 species worldwide. Each region has indigenous species plus established introduced species. In fact, many species have been widely distributed through commerce and they are considered cosmopolitan. The taxonomy of the family has been revised and keys to identification are available to all 12 genera and to all 35 species reported from North America *(471)*.

Adults are elongate, flattened, reddish brown to black, and 5 to 6 mm long. Unlike anobiids and bostrichids, the head is easily seen in dorsal view. The head is slightly deflected and constricted behind the eyes. The antennal club is two-segmented. Larvae are white and grublike; the body is C-shaped and enlarged at the thorax. The eighth spiracle on the abdomen is much larger than all the others; this characteristic distinguishes lyctid larvae from anobiid or bostrichid larvae.

Beetles in the family Lyctidae probably have a greater capacity for destroying portions of seasoned wood in a shorter period of time than any other native beetle. In comparison with other beetles, females lay many eggs, larval populations are high, and the life cycle is short. Other biological characteristics, however, severely restrict the frequency of infestations and extent of damage. For wood to be susceptible to lyctid attack, it must have at least 3 percent starch and pores (vessels) large enough for the insertion of eggs; eggs are not laid on the surface of wood. These requirements usually restrict damage by lyctid beetles to the unfinished sapwood portions of hardwoods, although heartwood of some wood species may be attacked also. Lyctid beetles are primarily problems of firms that produce, process, or sell hardwood products. Wood loses starch through respiration after tree felling, and infestations are rare in wood that has been in service more than 4 to 5 years *(131, 471)*. The frequency of infestations and the sum of damages are largely dependent upon hardwood species utilization and storage and processing procedures. In general, the likelihood of attack and the extent of damage are proportional to the amount of sapwood, the starch content, and the length of storage for unfinished hardwoods.

The wood of ring-porous species is more susceptible to attack than that of diffuse-porous species. Highly susceptible native woods include ash, white oak, pecan, and hickory. Other susceptible native hardwoods include cherry, elm, persimmon, sycamore, walnut, and many others. Many of the lighter colored, low density tropical hardwoods are highly susceptible to lyctid attack, e.g., banak *(Virola* spp.), luaun/meranti (*Shorea* spp.), and obeche (*Triplochiton scleroxylon* K. Schum.). Information on the identification, uses, and insect resistance of native and imported woods is available *(100, 136, 300)*.

Lyctid beetles do not infest domestic hardwoods as frequently as they once did; since the demand for these woods is greater now, prolonged storage is not required and there has been much improvement in transporting, processing, and drying.

Proper kiln drying eliminates infestations within raw hardwood materials, and use of water repellents seals pores of processed materials to prevent egg laying. Because of limited supplies, many of the most susceptible hardwoods such as ash, oak, pecan, and walnut are used as veneers, especially in furniture and paneling. Processes of drying and gluing veneers minimize lyctid beetle attacks.

Lyctid infestations are frequently associated with the use and movement of tropical hardwoods *(131, 275)*. This same association should occur in the United States because imported hardwoods are now frequently used as millwork, molding, picture framing, or as core material for plywood and paneling *(710)*. These and other solid wood products are exposed to lyctid attack during the long period from tree felling in the tropics to final use in this country.

Adults may emerge from infested wood at any season in heated buildings. Wood may be successfully attacked when its moisture content is between 6 and 30 percent. Larval development is better when the moisture content is near the midpoint of this range rather than at either extreme *(1038)*. Thus, wood in any centrally heated or air-conditioned building contains enough moisture for successful attack, and the same wood may be infested repeatedly until it is rendered useless. Infestations may also spread to other hardwoods nearby. In this manner and through the sale of infested products, lyctid beetles may become widely dispersed from a single source. Nevertheless, lyctid beetle damage is more common in the warmer Southern States than in the Northern States.

About 14 species in the genus *Lyctus* were reported from the United States. The **southern lyctus beetle,** *L. planicollis* LeConte, is a common native species. Adults are usually black but may be reddish brown; they are 4 to 6 mm long. Usually there is only one generation per year, but under favorable conditions a generation may be completed in 3 months or less *(206, 207, 1361)*. Information on rearing techniques has been published *(833, 1113, 1360)*.

Lyctus brunneus (Stephens), an introduced species, is the species most frequently associated with imported woods. Adults are 4 to 6 mm long; most of them are reddish brown, but some are black. *L. brunneus* is widely distributed and studied throughout the world. Rearing methods *(529, 1038)* have been developed and information on its biology summarized *(131, 567)*.

Lyctus africanus Lesne and *Minthea rugicollis* (Walker) are also often intercepted in imported hardwood products. Both species appear to be of tropical origin and apparently have not become established in this country.

Trogoxylon parallelopipedum (Melsheimer) is another common native species. Adults are smaller in average size than adults of *L. planicollis* and usually reddish in color. Studies of the biology of this species have been published *(206, 207)*.

Family Bostrichidae
False Powderpost Beetles

The family Bostrichidae contains about 455 species, most of which are indigenous to the tropics. Like the anobiids, members of the family vary considerably in habits—most species attack dead portions of trees, some breed in fungi, some are cosmopolitan pests of stored products, many species attack a wide variety of plants, and a few species reportedly attack weakened living trees. Like lyctid beetles, starch is an essential nutrient, and the sapwood portions of hardwoods are frequently attacked. Unlike lyctids, bostrichids do not reinfest wood after it is dry. Many of the larger bostrichid species in tropical regions cause extensive damage to unseasoned hardwoods used as packing crates and to bamboo products *(132)*.

Female beetles lay eggs in cracks or crevices on the wood surface or bore short tunnels in bark-free wood.

None of the more than 60 native species attacks bark-free wood except possibly the **leadcable borer**, *Scobicia declivis* (LeConte), in the West *(367)*. Seasoned wood suffers no damage of major economic importance caused by any species native to eastern North America. Attacks are initiated in partially seasoned wood containing bark. Females bore short tunnels into the outer sapwood and deposit eggs. Once attacks are initiated, larvae of many species may continue to feed and develop at a reduced rate. Adults may emerge from wood in use, usually within a year, but possibly even as long as 5 years after tree felling. Because bostrichids differ from lyctids in adult appearance, size of exit holes, and frass, bostrichids are referred to as false powderpost beetles. Many other species attacking trees are often called branch or twig girdlers, a name more appropriate to their habits.

Adults of native species are reddish brown to black and 3 to 6 mm long. They resemble adults of the family Scolytidae but differ in that the pronotum is tuberculate and rasplike, the tarsi are five-segmented, and the antennae are straight rather than elbowed. The antennal club is three- or four-segmented; the thorax is usually hoodlike, covering the head; and the posterior portion of the elytra is frequently concave and tuberculate. The femora and tibiae are broad and the latter are frequently toothed on one margin *(425)*.

Xylobiops basilaris (Say), the **redshouldered shothole borer**, is a common species, widely distributed over much of the Eastern United States. The adults are basically black but the basal part of the elytra is dull reddish-orange, hence the common name (fig. 110). Hickory, pecan, and persimmon are most frequently infested, but several other hardwoods are also attacked. Larvae feed parallel with the grain, mostly within the sapwood, but heartwood may be damaged to some extent. Populations may be high, thus extensive damage may result. Feeding may continue until the wood is very dry. Adults often emerge from wood within structures such as firewood.

The **apple twig borer**, *Amphicerus bicaudatus* (Say), is another common species in most of the Eastern United States. It breeds in dying wood such as large prunings, exposed roots, and injured branches of most shade and fruit trees. Some of the many other species and the woods they attack are: *Lichenophanes arminger* (LeConte)—various hardwoods, chiefly oak; *L. bicornis* (Weber)—sycamore, hackberry, oak, pecan, hickory, apple, beech, elm, black locust; *Scobicia bidentata* (Horn)—hickory, elm, oak, chestnut, hackberry, and sassafras.

Several native bostrichids commonly attack softwood timbers. Adults may emerge within structures from bark-covered wood that is used as structural timbers or rustic furniture. *Stephanopachys rugosus* (Oliver) is widely distributed in the Eastern United States. It and several other species in the same genus—*S. densus* (LeConte), *S. cribratus* (LeConte), and *S. hispidulus* (Casey)—breed in pine. *S. substriatus* (Paykull), found in most of the Northern States, attacks Douglas-fir and hemlock, as well as all species of pines and true firs.

Many of the tropical species are frequently intercepted during quarantine inspections at ports of entry to this country. Even though tropical in origin, at least two species are established in some Southern States.

The **bamboo powderpost beetle**, *Dinoderus minutus* (F.), occurs in Florida and Louisiana. It is frequently intercepted in bamboo products at ports of entry. Adults are reddish brown to brownish black and are 2.5 to 3.5 mm long. The wing covers

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Figure 110.—*Xylobiops basilaris*, a false powderpost beetle: A, adult; B, larval damage (note openings to frass-filled larval tunnels in cross section of a persimmon log).

are often redder than the rest of the upper surface. The female bores tunnels across the grain into bamboo culms at breaks in the rind and then deposits eggs in exposed vessels. The larvae often reduce products to masses of powder surrounded by easily shredded fibers.

In 1967, a large infestation of *Heterobostrychus aequalis* (Waterhouse), the **oriental wood borer**, was found in oak and mahogany lumber in a mill yard in southern Florida *(1218)*. This is one of the most common and most serious wood-boring beetles in India. It is widely distributed in Southeast Asia and it has been recorded attacking the wood from more than 35 species of trees. The adults are reddish brown to black and are from 6 to 13 mm long. The larvae become large, up to 13 mm in length. Usually the life cycle is 1 year, but it may take about 6 years.

Several species of western origin may be shipped to the Eastern States in infested wood. *Polycaon stouti* (LeConte) is commonly encountered. Its appearance is unlike other bostrichids in that the head is visible and the pronotum is not hoodlike. The pronotum and elytra lack tuberculate projections. The subcylindrical body is coal black and from 12 to 25 mm long.

Family Ptinidae
Spider Beetles

The common name for this family appropriately describes the appearance of these beetles. Adults are 2 to 4.5 mm in length. The head and pronotum are much narrower than the abdomen, the legs are long, the antennae are long and filiform, and the elytra are usually very convex and shiny. The majority of species breed in old grass roots or in dead bark. The **brown spider beetle**, *Ptinus clavipes* Panzer, and the **whitemarked spider beetle**, *P. fur* (L.), occasionally damage pine boards in old buildings. Both are cosmopolitan species that frequently damage dried vegetable and animal products in warehouses and museums. *Gibbium psylloides* (Czenpinski) occasionally is a pest in attics of houses where organic matter has accumulated.

Family Bruchidae
Seed Beetles

Members of the family Bruchidae are distinguished by their compact and usually oval bodies. Their small heads are prolonged into beaks, and their short wing covers leave the top of the abdomen exposed. The larvae are quite small and feed almost entirely in the seeds of plants.

Amblycerus robiniae (F.) is occasionally a pest in the Eastern United States. The female deposits her eggs on the pods of honeylocust and the larvae feed on the seeds within the pod. Adults are reddish brown and about 7 mm long. The body is clothed with grayish-yellow hairs and there are five rows of black spots across the elytra. *Gibbobruchus mimus* (Say) breeds in the seeds of the redbud and *Caryobruchus gleditsiae* (L.), in palmetto.

Family Chrysomelidae
Leaf Beetles

Leaf beetles are one of the larger families of Coleoptera, with about 2,000 species occurring in North America. The adults usually are medium size or small, short-bodied, and more or less oval. The legs are generally short, but in some species the femora of the hind pair are enlarged. There is great variation in coloring and markings, occasionally even within a species. In some species the entire body, elytra, and legs may have a bright metallic sheen. Some are hairless; others are pubescent or covered with scales or scalelike hairs.

Leaf beetle larvae are usually soft-bodied and frequently have highly pigmented sclerites. They vary greatly in shape, depending on their feeding habits. The head usually protrudes, except in the leafminers, and is bent downward for feeding. The body varies greatly in shape, from short and compact to depressed cuneiform, depending on whether the larva is free-living or a leafminer, casebearer, or root feeder.

All members of the family feed on the foliage of plants as adults or larvae, or both. The adults are diurnal and are usually slow moving. Species that are exposed in the larval stage feed gregariously, whereas leafmining larvae usually feed singly, each within its own mine. Adult feeding is characterized by the presence of holes eaten all the way through the leaf, or by skeletonization usually of the lower surface of the leaf. Free-living larvae either fasten themselves to the surface of the leaf to pupate, or move to the ground to do so. Leafmining larvae pupate either within the

mine, or they vacate it and pupate in the ground. There is considerable literature on this family *(53, 723, 724, 725, 1289).*

The **cottonwood leaf beetle**, *Chrysomela scripta* F., occurs throughout the United States and Canada and feeds on the leaves of poplar, willow, and alder. Adults are about 6 mm long. The head and thorax are black and the margins of the thorax are yellow or red. The wing covers usually are yellowish with black stripes, but are sometimes almost pure golden to black. Mature larvae are blackish and about 12 mm long. There are two whitish spots on each side. They are located at the site of the scent glands, one on each side of each segment except those on the prothorax and the last two on the abdomen. The scent glands emit a pungent odor when the larvae are disturbed.

Winter is spent in the adult stage under loose bark or debris or in clumps of grass. Emergence begins in early spring and the adults feed on unfolding leaves or on tender bark at the tips of twigs *(528)*. Eggs are deposited in groups of 15 to 75 on the undersides of leaves. The young larvae are gregarious and, feeding side by side, skeletonize the leaves. Later, they feed separately and consume the entire leaf, except the larger veins. At maturity they attach themselves to leaf surfaces, the bark, or to weeds and grass beneath the trees to pupate. There are several generations per year. Severe infestations occur occasionally and cause considerable damage.

The **aspen leaf beetle**, *C. crotchi* Brown, and *C. interrupta* F. occur commonly throughout the Eastern States. The adults and larvae of *C. crotchi* feed on poplar *(1093)*; those of *C. interrupta* feed on the leaves and at times on the tender bark of alder. *C. knabi* Brown feeds on poplar in the Northeastern States. It has also been observed feeding on willow in Tennessee.

The **elm leaf beetle**, *Pyrrhalta luteola* (Müller), an introduced species first recorded in North America at Baltimore, Md., well over a century ago, now occurs throughout most of the United States (fig. 111). Its hosts are all species of elm. In the Northeastern States, American elm is often severely attacked and seriously damaged. Farther west, Siberian elm is also frequently heavily attacked. European elms are especially subject to injury. Adults are about 6 mm long and yellowish to dull green, with a black stripe along the sides of the wing covers. There is also a short, dark spot at the base of each wing cover. Full-grown larvae are dull yellow, with two rows of black spots on the dorsum, and are about 12 mm long. The head, legs, and tubercles are black and there is a broad, yellow stripe down the middle of the dorsum. Pupae are bright orange-yellow with a few black bristles and they are about 5 mm long.

Elm leaf beetles spend the winter in sheltered dry places. In the Northeastern States most of them hibernate in house attics, barns, and sheds. During periods of warm weather in the winter many of these beetles become active and cause considerable annoyance by crawling into living quarters or onto windows. Spring emergence begins about the time the buds of elm begin to swell, and the adults fly to nearby elms and feed by chewing holes in the unfolding leaves. Egg laying begins in late May or early June, each female laying from 400 to 800 eggs *(1223, 1264)*. Hatching begins in about 1 week and the larvae feed for 2 or 3 weeks on the undersurfaces of the leaves. Only the veins and upper surfaces are left, and the leaves soon dry out and turn brown. Full-grown larvae crawl down the tree and pupate in bark crevices or at the base of the tree. In the Eastern United States there may be one or two complete generations and a partial third. Usually the first

Courtesy Agric. Res. Serv.

Figure 111.—Elm leaf beetle, *Pyrrhalta luteola*. A, undamaged elm leaf; B, elm leaf showing typical feeding damage, skeletonization, and perforation; C, egg mass; D, larvae; E, pupa; F, adult.

generation is the most injurious. Beetles maturing in the summer begin entering hibernation quarters as early as August, on or near the tree on which they fed.

Shade tree elms are often heavily defoliated, whereas those growing in the forest are usually not seriously infested. The native parasite, *Tetrastichus brevistigma* Gahan, and the coccinelid predator, *Coleomegilla maculata* (De Geer), occasionally exert a considerable degree of control in the Northeastern States *(102, 1263)*.

The **cherry leaf beetle**, *P. cavicollis* (LeConte) occurs in southern Canada and in the Eastern States southward through the Allegheny and Appalachian Mountains to North Carolina and westward to the Rocky Mountains. Its preferred host is pin cherry but it also feeds on plum, other cherries, and peach in heavily infested areas. The adult is red, shining, coarsely punctured, and about 5 mm long. Larvae are dark brown, with black and yellow spots, and are about 6 mm long.

The winter is spent in the adult stage. In the spring, eggs are deposited in the soil at the base of the tree or on the trunk near the base. The larvae climb the tree and feed on the foliage. Full-grown larvae return to the ground and pupate in the leaf mold or soil. There is one generation per year. The **gray willow leaf beetle**, *P. decora decora* (Say), and *P. tuberculata* (Say) feed on willows.

The **elm calligrapha**, *Calligrapha scalaris* (LeConte), has been reported from eastern Canada and from several widely distributed points in the Eastern United States. Its preferred and probably only host is elm. Adults are elongate-oval, creamy-white beetles from 8 to 10 mm long. The head and thorax are dark, metallic green. Each elytron bears from 10 to 14 metallic green spots, a dark-green, boot-shaped spot at the base, and a dark, metallic-green, irregular stripe along the inner edge. Full-grown larvae are hump-shaped and have yellow heads. The abdomen is light yellow or cream with a black line down the middle of the dorsum.

Adults overwinter in bark crevices, in sheltered places around the base of the tree, or in the top 2.5 to 5 cm of soil. When the adults emerge in the spring, they chew oval or circular holes in the leaves. The larvae devour entire leaves except the veins. When they reach maturity, they crawl down the trunk in search of places to pupate and spend the winter. In heavy infestations, they frequently occur by the thousands on the trunk or under the larger limbs. American elm is sometimes heavily defoliated and damaged in the Midwest *(283)*.

Calligrapha multipunctata bigsbyana (Kirby) sometimes completely defoliates willows over large areas in the Northeastern States. It is also a common species in the Midwest. The adult is a somewhat bronzed, metallic-green beetle about 6 to 8 mm long. The antennae and legs are reddish, and the margins of the pronotum and most of the elytra are pale yellow.

The **larger elm leaf beetle**, *Monocesta coryli* (Say), occurs throughout most of the Eastern United States from Georgia and Alabama northward to Pennsylvania, Ohio, Indiana, and Illinois and westward to the Plains States *(20)*. Its hosts are recorded as native and Japanese elms, river birch, pecan, hawthorn, and hazel. Slippery elm is especially favored. The adult is about 12 mm long. Its color is dull yellow to dark brown, with large, greenish patches at the ends of each elytron. Full-grown larvae are reddish brown, metallic lustered, and about 13 mm long.

Winter is spent as a full-grown larva in a cell 6 to 10 cm below the surface of the soil. Pupation occurs in early spring, and adult emergence begins in late May. The adults fly to the tops of their hosts, and feed on the leaves for several days. Eggs are deposited in masses on the undersurfaces of leaves; the larvae are gregarious and skeletonize the foliage; and there is one generation per year. Outbreaks have occurred in river bottoms of the Piedmont in the Carolinas and Alabama.

The **basswood leafminer**, *Baliosus ruber* (Weber), occurs in Canada and throughout most of the Eastern United States. Basswood is the favored host, but oak, maple, willow, birch, hophornbeam, apple, and cherry are also subject to attack. The adult is broad, flat, wedge-shaped, reddish yellow, and from 4.5 to 7 mm long. There are indistinct markings on its sides and on the apical half of the elytra. Full-grown larvae are about 6 mm long. The head and thorax are brownish red; the rest of the body is white.

The winter is spent in the adult stage under leaves and trash on the ground beneath infested trees *(578)*. In the Lake States, the adults emerge in the spring about the time basswood leaves begin to unfold. They feed on these leaves, skeletonizing them. Eggs are deposited singly at the edges of skeletonized areas on these leaves about mid-June, and the larvae feed by mining the leaves (fig. 112). Trees heavily infested for 2 to 3 years are characterized by thin crowns and the presence of dead branches; some trees may be killed. There is one generation per year.

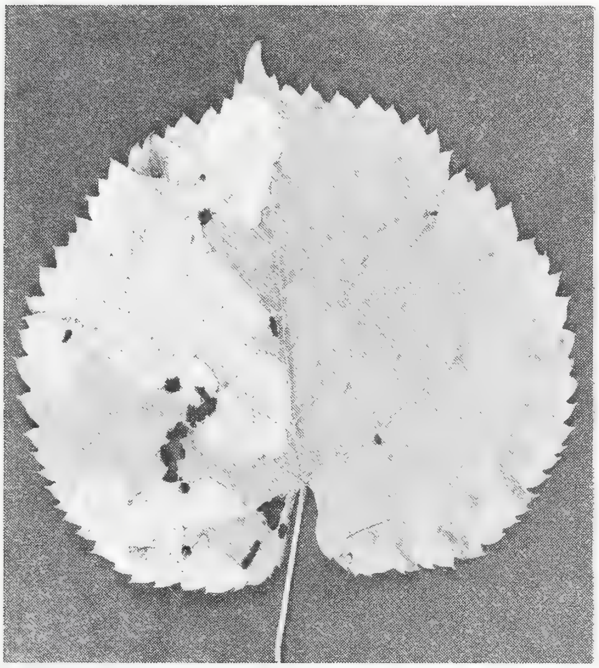

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Figure 112.—Leaf of basswood mined by the basswood leafminer, *Baliosus ruber*.

The **alder flea beetle**, *Altica ambiens alni* Harris, occurs in southern Canada and from Maine to Minnesota and New Mexico. It is sometimes a pest of alders growing along roadsides and in parks and other recreational areas. The adult is cobalt blue to greenish blue above, bluish black beneath, and about 6 mm long. Full-grown larvae are dark brown to almost black above, dark yellow beneath, and a little longer than the adult. In Maine, overwintering adults emerge in early spring and feed for a short time by eating small holes in the leaves before laying their eggs on the lower surface of the leaves. The larvae feed on both leaf surfaces and become mature in about 5 weeks *(1357)*. In the North there is one generation per year; in the South there may be two. The **elm flea beetle**, *A. carinata* Germar, a related species, feeds on elm; another, *A. subplicata* (LeConte), feeds on willow *(301)*.

The **pine colaspis**, *Colaspis pini* Barber, occurs from Maryland to central Florida and westward to east Texas. It feeds mostly on southern pines but also occasionally

on baldcypress and ornamental spruce. The adult is an elongate-oval convex, rusty-yellow or brown beetle with green reflections, and it is about 4.5 mm long. Full-grown larvae are sparsely covered with short hairs. Small clusters of longer hairs occur at the lower, outer edges of each body segment.

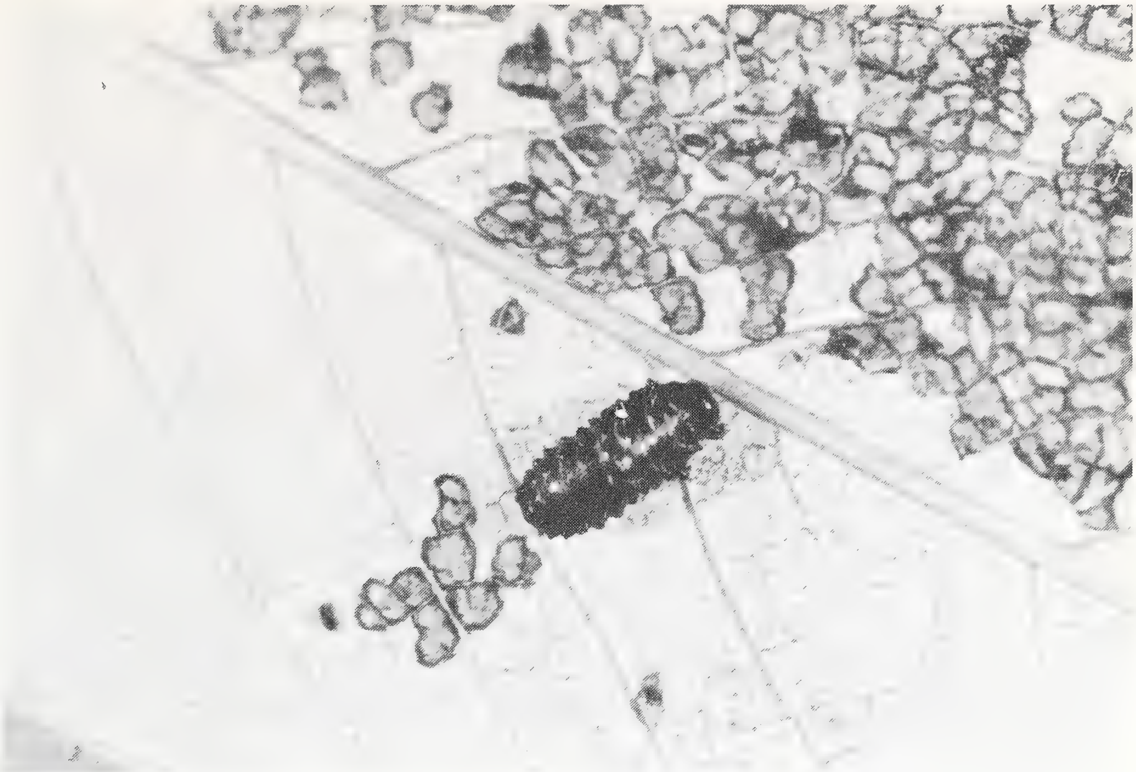
The winter is spent in the larval stage in cells in the soil. Pupation occurs in the spring and adults begin to emerge by early May. They feed on the needles of the host, chewing from the edges into the midrib. In light infestations, feeding is generally limited to the needles on new growth; whereas in heavy infestations needles over the entire crown may be attacked and entirely consumed. Where this occurs, infested stands appear as if scorched by fire. The larvae feed on the roots of grasses and herbaceous vegetation until fall, and then move deeper into the soil where they spend the winter. Infestations tend to occur on pines growing along the edges of stands bordering on grassland, or on isolated groups of pines growing in fields or yards. Severe infestations have been recorded in pine plantations in Florida, Georgia, and the Gulf Coast States. The biology of the species in Louisiana has been reported *(368)*.

The **locust leafminer**, *Odontota dorsalis* (Thunberg), occurs in southern Canada and throughout most of the Eastern United States. Its favored host is black locust, but several other tree species such as apple, birch, beech, cherry, elm, oak, and hawthorn are also attacked occasionally. The adult is an elongate, flattish beetle about 5 to 6 mm long. The head is black and the thorax and most of the wing covers are bright orange. The inner edge of each elytron is black, with the blackened area widening posteriorly. The elytra are also deeply pitted, and each elytron bears three longitudinal ridges. A full-grown larva is yellowish white, somewhat flattened, and a little longer than the adult.

The winter is spent in the adult stage in bark crevices or under debris on the ground. Overwintering adults emerge in the spring about the time the leaves begin to unfold, and feed for a short time on the leaves, skeletonizing the lower surfaces and eating holes in them. Eggs are deposited on the lower surfaces of leaves in groups of three to five. They overlap like shingles on a roof, are glued together, and are covered with excrement. All the larvae from a given group of eggs bore into a leaf and feed in a common mine. Later, they separate, and each larva feeds in its own mine. Before reaching maturity, a larva may mine several leaves. Pupation occurs in the mine, and there is one generation per year.

Outbreaks of the locust leafminer occur practically every year somewhere within its range, and black locust trees on tens of thousands of hectares are often defoliated. The defoliated trees are seldom killed, however, unless the damage is incurred during poor growing seasons. At such times trees may be killed in large numbers *(605)*. The eulophid parasite, *Closterocerus tricinctus* (Ashmead), is reported to have destroyed over 50 percent of the pupae in West Virginia infestations *(1258)*. Direct control is seldom attempted in the forest, but is sometimes desirable in parks and other recreational areas.

The **imported willow leaf beetle**, *Plagiodera versicolora* (Laicharting) (fig. 113), an introduced species, was first reported in this country from Staten Island, N.Y., in 1915 *(589)*. It is now widely distributed in the Eastern States and southern Canada (it has also been reported from Alaska) where it feeds on several varieties of willow and poplar. The adult is moderately stout, oval, and about 3.5 to 4.5 mm long. It is metallic blue or greenish blue, and sometimes tinged with red or bronze. Full-grown larvae are almost jet black and about 5 mm long. Rows of protuberances run both across and along the body.



Courtesy Can. For. Serv., Can. Dep. Environ.,
Sault Ste. Marie, Ont.

Figure 113.—The imported willow leaf beetle, *Plagiodera versicolora*. Note skeletonization of leaves by larvae.

The winter is spent in the adult stage under the bark, or in debris or tufts of grass around or near the base of trees. The beetles emerge in April or May and feed for a short period by skeletonizing the leaves or by cutting holes through them. Then the female lays irregular masses of eggs on the leaves. Hatching occurs in about a week. The larvae are gregarious and feed in groups or in rows on the leaf surfaces, which they skeletonize. Three generations per year, and a partial fourth, have been recorded in Massachusetts. Additional generations probably occur farther southward. Heavily infested trees may become entirely brown as early as mid-June. A considerable degree of natural control is exerted by the imported pupal parasite, *Schizonotus latus* (Walker) *(326)*. Extremely cold winters are also fatal to poorly protected adults.

Systena marginalis (Illiger) feeds on oak in the Midwest and on baldcypress in northern Florida and southern Georgia. The adult is dull, pale yellow except for two black lines along the front margin of the elytra and a single black line along the hind margin. The wing covers are densely and coarsely punctate. Adults are present from mid-June to late August and feed by gouging out linear-shaped punctures in the leaves. This usually causes part or all of a baldcypress leaflet to turn red and die. The beetles occur in large swarms that tend to move about, spending only 1 to 3 days in any one place. A single swarm may encompass more than a dozen trees.

Zengophora scutellaris Suffrian, an introduced species, feeds on cottonwood and other poplars from New York and New Jersey to Montana and New Mexico. The adult is about 4 mm long. The head, prothorax, and legs are yellow; the tarsal claws are toothed; there is a prominent tubercle on each side of the prothorax; the elytra are coarsely punctate; and the abdomen is black. The remainder of the body is yellow. Adults feed by skeletonizing the lower surfaces of leaves. The larvae feed singly in the soft inner tissues, chiefly against the upper surface of the leaf, making

large black blotch mines. When they become full grown they vacate their mines and drop to and enter the ground. Here they construct cells 6 to 10 cm below the surface in which to pupate. Trees heavily fed on by both larvae and adults may be completely defoliated.

Glyptoscelis pubescens (F.), the **hairy leaf beetle**, occurs primarily east of the Mississippi River from Canada to Georgia and feeds on various species of pines and, reportedly, spruce and hemlock *(671)*. The adult is elongate-oval, robust, broadly rounded posteriorly, dark brown with a brassy or golden sheen, and is from 7 to 10 mm long. It is also sparsely clothed with a mixture of white and brownish hairs (fig. 114). Adults feed on the edges of pine needles, causing them to turn brown. Defoliation has been reported in seed orchards of Virginia, shortleaf, and eastern white pines in North Carolina. *G. barbata* (Say) feeds on hickory and related trees from Connecticut to Pennsylvania. The adult resembles the adult of *G. pubescens* except that it is smaller and its upper surface is shining brown. The genus *Glyptoscelis* in the United States and Canada has been reviewed *(694)*.

Courtesy H. C. Coppel, Univ. Wis.

Figure 114.—*Glyptoscelis pubescens*, the hairy leaf beetle, ovipositing into a cocoon of the introduced pine sawfly on eastern white pine.

Many other chrysomelids also feed on various species of trees in the Eastern United States. A few of these and their hosts are as follows: *Pachybrachis peccans* Suffrian—hickory and birch; *P. tridens* (Melsheimer)—willow; *P. othonus* (Say)—ash and elm; and *P. carbonarius* Haldeman—oak; the **claycolored leaf beetle**, *Anomoea laticlavia* (Forster)—honeylocust, black locust, elm, live oak, and silktree; *Tymnes tricolor* (F.)—oak, walnut, and eastern hophornbeam; *Bassareus literatus* (F.)—hickory; *Derocrepis aesculi* (Drury)—buckeye; *Plagiometriona clavata* (F.)—sycamore, basswood, and oak; *Neochlamisus platani* Brown—sycamore; *Xanthonia decemnotata* (Say)—oak, beech, and elm; *Paria sexnotata* (Say)—redcedar; *P. quadrinotata* (Say)—walnut and mountain-ash; and *Syneta ferruginea* (Germar)—birch and oak.

Family Lucanidae
Stag Beetles

Stag beetles are distinguished by very large mandibles, which in the males of certain species are branched like the antlers of a stag, and by the plates of the antennal club, which are rigid and cannot be opened or closed. They are usually found in or beneath rotting logs or stumps. The larvae feed on the juices of rotting wood.

The **giant stag beetle**, *Lucanus elaphus* F., the most familiar species, infests dead stumps in the South. Adults are large, fearsome insects, up to 60 mm long. Male mandibles are branched and are more than half as long as the body. *Pseudolucanus capreolus* (L.) is also a common species. It breeds in the trunks of old, partly decayed trees such as apple, cherry, willow, and oak. The adults fly at night and are frequently attracted to lights. Other eastern species include *Platycerus quercus* Weber, *Ceruchus piceus* (Weber), *Dorcus parallelus* Say, and *Sinodendron rugosum* Mannerheim. The first three breed in moist, almost completely decayed logs. *S. rugosum* breeds in decayed alder, willow, and poplars.

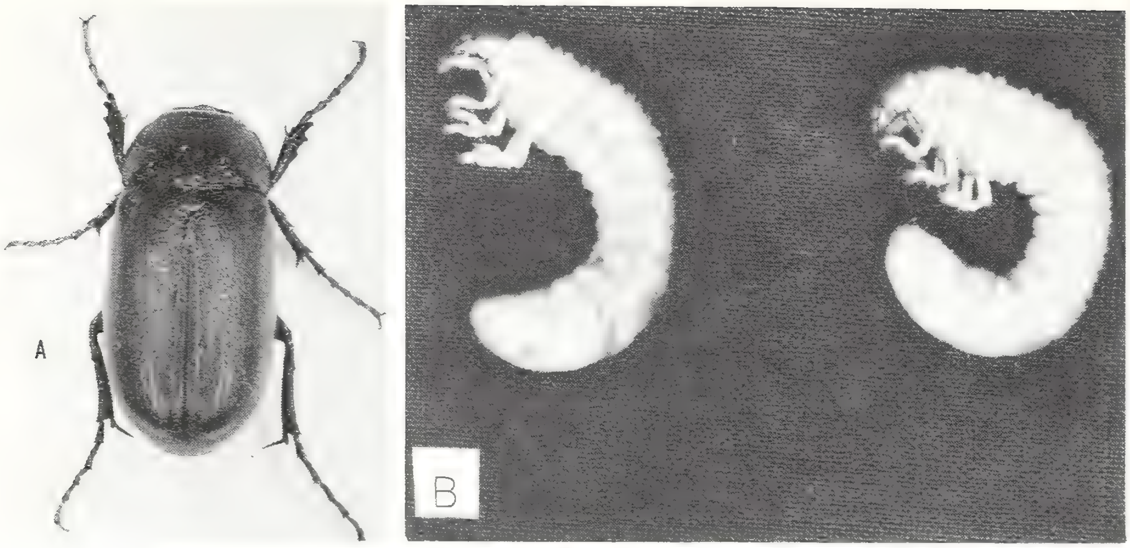
Family Scarabaeidae
Scarabs

The family Scarabaeidae is represented in the United States by more than 1,400 species, the majority occurring in the eastern half of the country. Depending on their feeding habits, members of the family fall into two distinct groups. One group comprises the so-called dung beetles, the larvae and adults of which are saprophytic, feeding on such materials as dung, carrion, and decomposing plants. The second group consists of species whose larvae feed on the roots or juices of living plants, decaying vegetable matter, rotten wood, leaf mold, and sometimes manure. The adults feed chiefly on the foliage of plants. They are commonly referred to as lamellicorn leaf chafers. Many of the plant-feeding species are important pests of nursery, plantation, woodlot, shade, and forest trees. The adults of most of these are nocturnal and are strongly attracted to lights.

Scarab beetles have stout bodies, the last three to six or seven segments of the antennae are leaflike and capable of being opened or closed. Their front legs are fitted for digging. The larvae or grubs are usually thick, white or yellow, enlarged posteriorly, bent in the shape of a crescent, and have well-developed legs.

The genus *Phyllophaga* is represented in the United States and Canada by more than 100 species, the majority of which occur in the East *(756)*. The adults, commonly called May or June beetles, are robust, oval, light straw to very dark brown, and from about 12 to 25 mm long (fig. 115A). The wing covers are smooth and shiny or are covered with short hairs. The antennae are lamellate and end in three-jointed clubs; the tarsal claws are armed with a small tooth near the middle. The larvae, commonly called white grubs, are milky white, strongly curved, and about 25 mm long at maturity (fig. 115B). The head is brownish, all of the hind parts are shiny, and body contents are visible through the skin.

The adults of certain species are most abundant in the spring, usually in May; others reach peaks of abundance in June or July *(1030)*. They tend to stay out of sight under stones, leaves, or trash, or in the soil during the day; and to fly, mate, and feed at night. Eggs are laid in masses in the soil at depths of 8 to 18 cm, each egg being placed in a cavity in the center of a ball of dirt. Newly hatched larvae feed on organic matter; then they move to tender roots of seedlings and other plants to feed. The winter is spent in the larval stage at depths determined by temperatures and frost levels. Pupation takes place in the soil at depths of a few centimeters to 30



A, F-532842; B, F-494654

Figure 115.—*Phyllophaga* spp. A, adult; B, white grubs.

or more. In the South, the life cycle is completed in 1, 2, or 3 years; in the Central States, 2 to 3 years are required; farther north, from 3 to 4 years are needed *(1141)*.

Phyllophaga larvae, or white grubs, have caused heavy losses in forest nurseries and plantations in the South, the East, and Central and Lake States. Also, here and there throughout the region, many trees are lightly to heavily defoliated by the adult beetles every year, especially in woodlots and around the edges of forest stands. A few of the more common and important species are discussed briefly below.

Phyllophaga drakei (Kirby) occurs throughout most of the Eastern United States and southern Canada. Adults are dark brown, shiny, and about 25 mm long. They feed on the leaves of beech, birch, dogwood, maple, basswood, elm, and willow. The larvae are important pests in forest nurseries and plantations in the Lake States and Canada.

Phyllophaga luctuosa (Horn) occurs primarily along the Atlantic and Gulf Coasts in sandy, oak-pine regions, but also farther north and inland to Tennessee, Oklahoma, and Iowa. Adults are dark brown to black, moderately shiny, and about 21 mm long. They feed on persimmon, mulberry, tupelo, walnut, willow, beech, birch, and loblolly and longleaf pines. The larvae are often destructive in nurseries and, probably, plantations.

Phyllophaga tristis (F.) occurs throughout the Eastern United States and in southern Canada. Adults are light or dark yellowish-brown or slightly reddish, and about 12 mm long. They seem to prefer the foliage of oaks but also feed on maple, persimmon, hickory, elm, and willow. The larvae have caused serious losses in nurseries in the Lake States.

Phyllophaga prununculina (Burmeister) occurs in the South Atlantic and Gulf Coast States. It is especially common in the Sand Hills of South Carolina. Adults are reddish brown to black, with the surface either shining and slightly pruinose, or dull smoky, and are 12 to 18 mm long. They feed on pines, especially loblolly and longleaf, and sometimes oaks and persimmon. The larvae have caused serious losses in pine nurseries and plantations in South Carolina.

Phyllophaga rugosa (Melsheimer) occurs mostly in the Northern States and southern Canada. Adults are reddish brown to black, shiny, and from 18 to 25 mm long. They feed on a wide variety of hardwoods. The larvae are often destructive in coniferous nurseries in the Lake States.

Phyllophaga crenulata (Froelich) occurs throughout the Eastern United States. Adults are brown, with a covering of short, recumbent hairs, and are about 17 to 20 mm long. They feed on a wide variety of hardwoods, especially persimmon, hickory, basswood, willow, birch, and buckeye. The larvae are often serious pests in coniferous nurseries in the Lake States.

Phyllophaga forsteri (Burmeister) occurs generally throughout the Eastern United States. Adults are reddish brown and shiny, have dusky heads, and are about 16 mm long. They feed on a wide variety of hardwoods such as beech, birch, elm, magnolia, maple, tupelo, walnut, and willow. There are also reports of their feeding on pine. The larvae are often destructive in nurseries in the South.

Phyllophaga prunina (LeConte) occurs throughout the central part of the United States east of the Rocky Mountains. Adults are chestnut brown to black and about 18 mm long. They feed on various hardwoods, such as beech, elm, walnut, basswood, and willow. Feeding on pine has also been observed. The larvae are sometimes injurious in nurseries in the Lake States.

Phyllophaga implicita Horn occurs mostly in the Mississippi and Ohio River Valleys. Adults are orange-brown to brown (with the head and thorax darker), shiny, and about 14 to 18 mm long. They feed on beech, dogwood, elm, sycamore, tupelo, walnut, willow, basswood, maple, and other plants. The larvae killed millions of seedlings in nurseries in Iowa in the thirties.

Phyllophaga micans (Knoch) is found over most of Eastern United States. Adults are brownish black, and from 15 to 17 mm long. They feed at night on female flowers and needles of pines. Although damage is not common, one report from Louisiana cites that 14 percent of the pine conelets were killed by this scarab *(547)*.

The genus *Polyphylla* is represented by a number of species in the Eastern United States, a few of which are sometimes injurious. The beetles are somewhat larger than those of the genus *Phyllophaga*. A few species are entirely brown while the remainder are brown- or white-striped. They are distinguished further by their massive antennal clubs, which consist of six or seven extremely long, thin, flat, parallel, leaflike plates.

The larvae of *Polyphylla variolosa* Hentz have caused heavy losses in coniferous nurseries in the Northeast. The larvae of *P. occidentalis* (L.) have been observed feeding on the roots of pine seedlings, but they prefer the roots of grasses. They would appear to be potentially harmful in nurseries and plantations. *P. hammondi* LeConte occurs in the western part of the Central States and has the interesting habit of depositing its eggs in rotten wood.

The genus *Serica* contains a number of species, the adults of which closely resemble those of the genus *Phyllophaga* except for their much smaller size and their regularly spaced, elytral striae. They are usually less than one-fourth as large as May beetles. The adults are sometimes abundant enough to cause noticeable defoliation in hardwood stands. The larvae have also been known to cause damage in heavily infested nurseries, but they are usually not very destructive. Adults emerge from mid-May to mid-August but are usually most abundant in June. The life cycle requires 2 to 3 years. Common species include *S. sericae* (Illiger), which is often abundant; *S. tristis* LeConte, which has been known to defoliate spruce in plantations in southern Canada; and *S. vespertina* (Gyllenhal) and *S. intermixta* Blatchley.

The genus *Dichelonyx* is represented in eastern North America by many species. The beetles are small, about 6 to 12 mm long, and are often brightly colored. A distinguishing characteristic is the presence of two spurs on each middle and hind

tibia. The larvae are grubs, which never exceed 18 or 20 mm in length. Adults are most common in June and July, and the life cycle requires 2 to 3 years *(1056)*.

Dichelonyx albicollis (Burmeister) is a well-known species. It has been recorded from New Jersey, Michigan, and Ontario and feeds during both the day and night on the needles of pine, especially jack pine. The adult is greenish, shiny, and about 12 mm long. *D. elongata* (F.) occurs from New England and New Jersey to Oklahoma and Kansas. The adults feed at night on the leaves of various hardwoods, especially sweet birch and alder. The adult is smaller and somewhat darker than the adult of *D. albicollis*. A third species, *D. subvittata* LeConte, has been recorded feeding on oak, hazel, and pine from New England to the Lake States and in southern Canada.

The genus *Diplotaxis* contains a number of species that feed mostly on conifers, especially pines. The beetles are usually brown or reddish brown and, except for having five visible ventral abdominal sternites, resemble members of the genus *Phyllophaga*. The exoskeleton is also quite hard and rigid. *D. sordida* (Say) occurs commonly on red and jack pines in the Lake States, and the larvae have caused serious damage in nurseries and plantations in New York. The adult is slate colored with yellowish hairs on the pronotum, and it is about 10 to 12 mm long. *D. liberata* (Germar) also occurs commonly on pines in the Lake States. The adult is blackish, hairless, and about 12 mm long.

The **Asiatic garden beetle**, *Maladera castanea* (Arrow), an introduced species first recorded in North America in New Jersey in 1921, is now widely distributed in the Eastern States south to South Carolina. Adults are usually cinnamon brown and about 6 to 12 mm long. They fly at night and feed on more than 100 species of plants, including forest and shade trees such as maple, willow, boxelder, buckeye, and ailanthus. Young pines, hemlocks, and yews in nurseries are defoliated occasionally and seriously injured. The roots of rhododendron and azalea are damaged occasionally by the larvae.

The **rose chafer**, *Macrodactylus subspinosus* (F.) is widely distributed in the Eastern United States. Adults are tan to reddish brown, densely covered with dull, yellow scales or hairs, and have long reddish-brown legs. They skeletonize the leaves of a wide variety of hosts, including many species of forest and shade trees (fig. 116). In heavily infested areas, they appear in swarms in late May or early June and feed first on the opening buds. Later, they attack the flowers, fruit, and foliage. The larvae feed mostly on the roots of grasses but may also attack the roots of tree seedlings.

The **European chafer,** *Rhizotrogus (=Amphimallon) majalis* (Razoumowsky), an introduced species first recorded in New York in 1940, now occurs in several Eastern States and southern Ontario *(228)*. The adult is oval-shaped, light brown or tan, and about 14 mm long. A distinguishing characteristic is its toothless, uncleft, hind tarsal claw. During the peak of the flight season they are often seen swarming around various trees and tall shrubs. The larvae feed on the roots of a wide variety of plants, including the seedlings of such tree species as spruce and Douglas-fir *(1189)*.

The **pine chafer**, *Anomala oblivia* Horn, occurs from New York to the Lake States and south to Georgia. Male beetles have the head and pronotum greenish bronze and the elytra dark tan. They are about 6.5 mm long. Females are light tan and about 9 mm long. They feed mostly on the new needles of various pines, eating notches in them just above the sheath and causing the ends to die. Heavily infested trees become brownish or scorched in appearance. Needle browning has occurred

Courtesy Conn. Agric. Exp. Stn.

Figure 116.—Birch leaf skeletonized by the rose chafer, *Macrodactylus subspinosus*.

on several thousand hectares of young loblolly pines in southeastern North Carolina. The base of the damaged needle usually survives, however, and the needle grows to about one-half its normal length. The winter is spent in the larval stage 6 to 10 cm deep in the soil. Pupation occurs in the spring, and the adults emerge in June or earlier. Eggs are deposited in the soil near their pine hosts. Hatching occurs in 10 to 15 days and the larvae feed on the roots of various plants, including trees, until the onset of cold weather. There is one generation per year.

Infestations of the pine chafer tend to occur in open pine stands and plantations. Numerous outbreaks have occurred in the Lake States and the South. The majority were short-lived and limited in size, but some outbreaks were quite extensive and lasted for several years. *A. lucicola* (F.) occurs from New England to the Lake States and Kentucky. It severely damaged larch seedlings in a nursery in New York.

The **Japanese beetle**, *Popillia japonica* Newman, an introduced species first recorded in North America near Riverton, N.J., in 1916, now occurs in all or parts of at least 15 States from New Hampshire and Vermont to Georgia and Ohio *(427)*. Spot infestations have also been recorded in many other States and in Ontario and Nova Scotia, Canada. The adult is broadly oval and nearly 12 mm long. The body is a bright, metallic green; the legs, a darker green; and the elytra, a coppery brown. There are two small tufts of white hairs just behind the wing covers and five patches of white hairs on each side. The wing covers are shorter than the abdomen. Full-grown larvae are about 25 mm long, typically grub-shaped, and have the last two rows of spines on the underside of the last abdominal segment arranged in the shape of a V.

The Japanese beetle feeds on the foliage, flowers, and fruits of a wide variety of plants. It is present north of Florida, in most States east of the Mississippi River and

south of Wisconsin and Minnesota, and in California. Many species of forest and shade trees are subject to defoliation, especially Japanese and Norway maples, buckeye, sycamore, gray birch, walnut, Lombardy poplar, basswood, mountain-ash, and American, English, and Siberian elms. Feeding is usually confined to young, tender leaves. Damaged leaves may be skeletonized or they may also have large, irrregular holes chewed out. In heavily infested areas, the trees may be almost entirely defoliated. The larvae may also seriously damage the roots of ornamental nursery stock.

The winter is spent in the larval stage in the soil. Pupation occurs in early spring, and the adults emerge from late May to early July. They are gregarious and are often found feeding in masses on certain plants, while nearby plants are uninfested. Female beetles enter the soil to depths of 3 to 10 cm to deposit their eggs. Moist, loamy soil covered with closely cropped grass is a favorite site. There may be two generations per year in the southern parts of the species' range. Farther north, the life cycle may require 2 years.

Disease pathogens, especially the bacterium, *Bacillus popilliae* Dutky, often destroy large numbers of the larvae. Several introduced parasites, *Tiphia vernalis* Rohwer and *T. popilliavora* Rohwer in particular, also exert a considerable degree of control *(427)*.

Cotalpa lanigera L., the **goldsmith beetle**, occurs throughout the Eastern United States and feeds on the foliage of various hardwoods, such as aspen, oak, and willow. The adult is broadly oval, convex, and from 20 to 26 mm long. It is a brightly colored beetle; the elytron is lemon yellow, and the head and thorax burnished golden. The venter is greenish to copper and covered with whitish wool. The legs are reddish yellow. Full-grown larvae are about 43 mm long. The head is tan and the underside of the last abdominal segment is thickly covered with hooked spines. Adults emerge in late spring and the females deposit their eggs in the soil. The larvae feed on the roots of various plants, probably including young conifers. Adults have been observed fairly commonly in nurseries in the Lake States. The life cycle requires from 2 to 3 years for completion.

The **green June beetle**, *Cotinis nitida* (L.), one of the most widely recognized members of the family, occurs throughout much of the Eastern United States, most commonly in the Atlantic and Gulf Coast States and in the Mississippi River Valley. The adult is usually velvety green above, with the margins orange-yellow, and is about 10 to 25 mm long. The undersurface is shining green and orange-yellow, and the head is armed with a hornlike process. Full-grown larvae are up to 50 mm long and have the interesting habit of crawling on their backs.

Adults are most numerous during June and July, and the females deposit their eggs in soil rich with organic matter. The larvae feed on the organic matter during the remainder of the season and then hibernate. In the spring, they move close to the surface and feed on both dead vegetation and the roots of living plants. Lawns and golf courses are often damaged severely. Seedlings in forest nurseries are sometimes injured.

The genus *Dynastes*, which contains the largest known beetles, is represented in the Eastern United States by only one species, the **eastern Hercules beetle**, *D. tityus* (L.). It has been recorded from New York, Indiana, and Arkansas south to the Gulf of Mexico. *D. tityus* breeds in decayed hardwood stumps and logs, and is also found occasionally in cavities in the bases of living trees *(488)*. The adult is very large, from 40 to 60 mm long, and is usually greenish gray or tan except for mottlings or blotchlike areas of black. The male is armed with a large pronotal horn

that projects forward and almost meets another horn that projects upward from the front of the head. Females are somewhat smaller than the males and are without horns. The habits of the adults are not well understood; however, they have been observed feeding on sap oozing from wounds on ash trees.

The genus *Xyloryctes* is represented in eastern forests by three or four species, one of which, the **rhinoceros beetle**, *X. jamaicensis* (Drury), is common in hardwood stands in the South. The adults are robust, shiny beetles, about 28 mm long. They are dark chestnut to blackish brown above, and paler and thickly clothed with reddish hairs below. The male has a single, large curved horn on top of the head. In the female, a large tubercle replaces the horn. The larvae are usually found in leaf mold on the forest floor. Adults are usually found in the vicinity of ash trees.

At least four species of the genus *Pelidnota* occur in eastern forests, one of which, *P. punctata* (L.), is fairly well known. The larvae are usually found in decayed hardwood stumps but sometimes in decaying roots and logs. The adult is about 20 mm long and reddish brown above, with three black spots on each wing cover and one on each side of the pronotum. The base of the head, the scutellum, and the entire underside of the body are deep bronzed green. The species is not injurious.

The genus *Parastasia* is represented in eastern forests by several species. The most common and widely distributed one is *P. brevipes* LeConte. The larvae are found most commonly in decayed hardwood stumps, roots, and logs. Adults are blunt, convex, dark chestnut-brown, and about 16 mm long. The species is not considered to be injurious.

The genus *Osmoderma* is represented in eastern forests by at least four species, two of which, *O. eremicola* Knoch and *O. scabra* (Beauvais), are fairly common. The larvae feed in decayed cavities of dead or dying trees or logs. The adults are broadly oval and depressed dorsally and have heavy leathery elytra; *O. eremicola* is dark chestnut-brown, smooth and shiny, whereas *O. scabra* is bronzy purple-black and rough in texture. They are approximately 25 mm long. When handled, they emit a strong leatherlike odor.

The genus *Trichiotinus* contains several species, the adults of which are frequently seen around flowering trees and shrubs, cherry in particular. They are variegated, the body is densely pubescent, the elytra are almost as wide as long, the legs are long and slender, and they range in length from 9 to 15 mm. The larval stage is spent in old logs and stumps.

Family Elateridae
Click Beetles, Wireworms

Click beetles are so-called because of the presence of a spine on the prothorax that snaps into a groove on the mesosternum with an audible click. This mechanism enables an adult lying on its back to throw itself into the air and land on its feet. The larvae are known as wireworms because of their long, narrow, fusiform, tough-skinned bodies. Forest-inhabiting species are predominantly phytophagous, but a few are predacious on other insects, such as wood borers and sawflies in cocoons in the soil. Species that feed on forest vegetation usually confine their attacks to dead and often well-decayed wood and are of little economic importance. The wireworms of New York State have been reported *(303)*.

The **eyed click beetle**, *Alaus oculatus* (L.), is a voracious feeder on various species of borers in hardwoods and the related species, *A. myops* (F.), on borers in pines. Adults of *A. oculatus* are grayish black, with two large eyelike spots on the prothorax, and are 25 to 50 mm long. Adults of *A. myops* are more slender and darker, and are only about 20 to 40 mm long. They also have eye spots.

Other predacious species include *Lacon discoidea* (Weber) and *L. avita* Say that are found in pines, and *Hemicrepidus bilobatus* (Say) that occurs in hickory. *Ctenicera triundulata* (Randall) and *C. nitidula* (LeConte) have been observed feeding on cocoons of the European spruce sawfly in Canada *(879)*, and an undetermined species of *Ctenicera* was found feeding on the larch sawfly in Minnesota *(332)*.

Family Cleridae
Checkered Beetles

This is one of the most important families of insect predators attacking injurious forest insects. The adults are active, antlike, brightly colored, hairy beetles about 3 to 13 mm long. They feed on adult beetles. The larvae live in the galleries and tunnels of bark beetles and wood borers and destroy the immature stages of these insects.

Adults are distinguished by their 11-jointed and generally serrate antennae, the outer joints of which are longer and form open or compact clubs. The tarsi are five-jointed and the first four joints bear membranous appendages. Larvae are soft-bodied, elongate and parallel-sided, frequently highly colored though often white and thin-textured, and are from 9 to 13 mm long.

Most species spend the winter in the larval stage. Others overwinter as pupae or as adults in pupal cells in the bark. The larvae travel down the tunnels of their hosts eating one larva after another. Some are capable of consuming several times their own weight of these larvae *(141)*. A few of the more important predators of forest insects are discussed below.

Chariessa pilosa (Forster) is one of the most common species in eastern forests. Its known hosts include several species of borers in hardwoods, and the smaller European elm bark beetle. The adult (fig. 117) is a wedge-shaped, flattened beetle about 6 to 13 mm long. The thorax is red with two black stripes and the wing covers are black with dense, fine punctures. The larva is fairly robust, widest at the middle, and of a bluish tinge. Adults are often observed feeding on insects attracted to freshly cut logs during the summer.

F-519949

Figure 117.—Adult of *Chariessa pilosa*, a predator of wood-boring larvae.

Thanasimus dubius (F.) is one of the most important predators of the destructive bark beetles in the Eastern United States *(98, 445, 868)*. The adult is a brightly colored, hairy beetle about 7 to 10 mm long. The head, thorax, and base of the wing covers are dull red; the antennae and legs are red to pitch black; and the wing covers are mostly black with crossbands of whitish hairs. The larva is elongate, fusiform, and purplish with brown sclerotized areas.

Winter is spent in the larval, pupal, or adult stages. In early spring, the adults emerge and fly to beetle-infested trees or logs and feed on bark beetles as they emerge from hibernation. Eggs are deposited in entrances to bark beetle galleries. Young larvae feed on bark beetle eggs; older ones feed on beetle larvae, pupae, and adults. Pupation occurs in cells in the outer bark *(590)*.

Enoclerus nigripes (Say) larvae feed on bark beetles in conifers, and on wood borers in hardwoods. Adults are brightly colored and about 8 to 12 mm long. The head, thorax, base of the wing covers, and the undersides are dull red; the remainder is black except for two yellowish crossbars on the wing covers. The larvae are similar to those of *T. dubius*. The **blackbellied clerid**, *E. lecontei* (Wolcott), has many hosts including bark beetles and weevils in pine, spruce, and juniper. It also feeds on bark beetles, weevils, and small borers in hardwoods.

Monophylla terminata (Say) feeds on borers and bark beetles in hardwoods. There also are reports of its feeding on white pine weevil larvae in white pine. Adults are about 4 to 8.5 mm long. The eyes are deeply notched in front, the last joint of the antenna is as large or larger than all of the others combined, the thorax is yellow with a black disk, and the sides of the wing covers are yellow. The larvae are white, soft-textured, and bear two well-separated hooks on the ninth abdominal segment.

Cymatodera bicolor (Say) is an important enemy of roundheaded and flatheaded borers in hardwoods in the Eastern United States. Adults are about 5 to 10 mm long. The color is dull blackish except for the legs, thorax, and basal joints of the antennae which are reddish yellow mixed with black. The larvae are purplish.

Tarsostenus univittatus (Rossi) is an important predator of powderpost beetles and other borers in dry, seasoned wood. The adult is small, slender, and shiny black except for a white mark across the middle of the elytra. The larva is very small and a light violet, except for brown or yellow markings. There are two recurved hooks on the ninth abdominal segment.

Neichnea laticornis (Say) feeds on various species of bark beetles in the Middle Atlantic States. The adults are small, slender, and black except for a spot on the head and the sides of the thorax, which are golden yellow.

Many other clerids are also predacious on various forest insects in the Eastern States. *Priocera castenae* Newman feeds on bark beetles in conifers; *Phlogistosternus dislocatus* (Say) and *Orthopleura damicornis* (F.) feed on the larvae of borers and bark beetles in the twigs of hardwoods; *Cregya oculata* (Say) feeds on larvae of borers and bark beetles in both hardwoods and conifers. Descriptions of clerids occurring in Ohio are available *(683)*.

Family Dermestidae
Dermestid Beetles

Dermestid beetles are compact, oval to convex, and usually extremely hairy. Some are spotted with gray, brown, or orange hairs which rub off easily. The larvae are cylindrical and covered with long hairs. Some larvae are soft; others are hard-shelled.

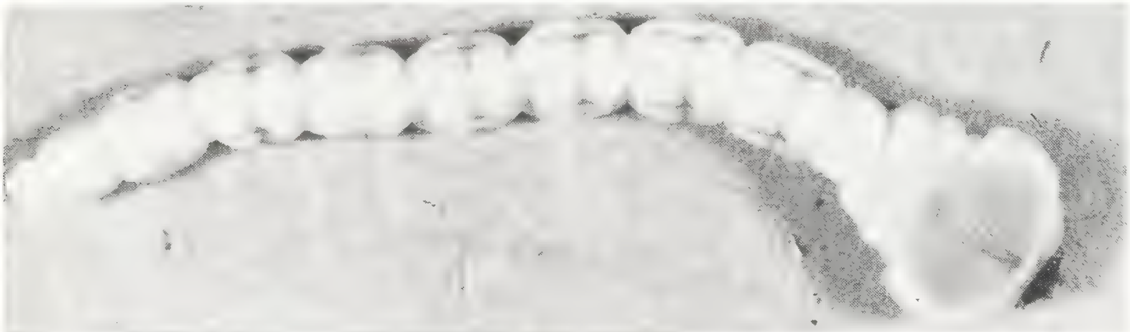
A few species are found under the bark of trees where they feed on dead insects. Some are troublesome pests in collections of insects or stuffed animals, on which they feed. The **hide beetle**, *Dermestes maculatus* De Geer, and the **larder beetle**, *D. lardarius* L., have damaged cargoes of lumber in ship holds where hides were stored previously. In efforts to construct pupal chambers, *D. maculatus* has also been known to damage seriously the surface of lumber in warehouses. The majority of dermestids feed on skins, dried meats, furs, and carpets.

Family Buprestidae
Flatheaded Borers

The flatheaded borers include several destructive pests of forest and shade trees. More than 150 species and varieties have been recorded east of the Mississippi River *(443)*. The larvae of all species are borers, and they feed in all parts of the tree. Some mine the leaves, and some construct tunnels in the inner bark and outer wood of the trunk, branches, and roots. The majority of species, however, excavate winding tunnels through sound and decaying sapwood. Many bark-boring species are capable of girdling and killing both healthy and injured trees. Wood-boring species are often highly destructive of recently felled saw logs, often seriously reducing or destroying their usefulness as lumber.

Buprestid beetles are usually somewhat flattened or oval-shaped and are beautifully marked or metallic colored. The head is strongly deflexed and is inserted into the prothorax to the eyes. The antennae are serrate, 11-jointed, and inserted on the front; the prosternum is prolonged behind and fits into the mesosternum; the elytra usually cover the abdomen; and the first two of the abdominal sternites are fused.

Buprestid larvae are distinguished primarily by well-developed ambulatory plates on the upper and lower surfaces of the first segment behind the head, by the presence of a central line, groove, or V on the upper plate, and by the absence of legs. The larvae of all bark- and wood-boring species are typically "flatheaded," a condition caused by the greatly enlarged first and sometimes second and third thoracic segments (fig. 118). Leafmining larvae are flattened, rather oval-shaped, deeply notched at the sides, and gradually taper toward the rear. The true head in all larvae is comparatively small, more or less retracted into the first thoracic segment, and scarcely visible.



Courtesy R. T. Franklin, Univ. Ga.

Figure 118.—Typical larva of a buprestid or flatheaded borer.

Bark- and wood-boring buprestids deposit their eggs singly or in masses either on the bark, in crevices in the bark or wood, or under the bark at the edges of wounds. Weakened, injured, dead, or dying trees and stumps are usually attacked. Occasionally, green trees are also infested. The larvae feed either under the bark, in the sapwood or heartwood, or in two or more of these places. Their mines are

winding and usually oval in cross section. Eventually, they terminate in elongated pupal cells that are connected to the surface by short, oval exit holes. Characteristically, the mines are usually packed tightly with layers of sawdustlike borings and pellets and their walls are scarred with fine, transverse lines. Many wood-boring species spend the winter as adults in pupal cells. A few overwinter in the larval stage. The life cycle usually requires 1 to 2 years, but in certain species it takes many years.

Acmaeodera pulchella (Herbst), the **flatheaded baldcypress sapwood borer**, breeds in baldcypress in Eastern and Southern States. The adult is blue-black to blackish and about 6 to 10 mm long. In some individuals the thorax is dull bronze and the wing covers and outer angles of the thorax are marked with spots and patches of waxy yellow. Full-grown larvae are about 13 mm long and the prothoracic plates are marked by brownish median grooves or lines. The sapwood of dead and dying baldcypress trees and recently cut baldcypress logs is subject to severe attack and damage. The removal of unseasoned logs from the woods before the adults fly in the spring, or girdling trees in the fall that are to be felled in the spring, should aid in the reduction of damage.

The **twolined chestnut borer**, *Agrilus bilineatus* (Weber), occurs in southern Canada and throughout the Eastern United States. It breeds in various hardwoods, preferably chestnut and several of the oaks *(348)*. Trees weakened by drought or defoliation, and trees with low root starch *(1244)* are usually attacked. Adults are 6 to 12 mm long, subcylindrical, and black with a more or less greenish tinge. The sides of the thorax and elytra are clothed with light golden-yellow pubescence, and each elytron is marked with a stripe of the same color. The larva is slender, considerably flattened, about 25 mm long, and has two spines at the posterior end.

Winter is spent in the final (fourth) instar in pupal cells constructed in the outer layers of the sapwood and sometimes in the bark *(249)*. In the spring, the adults emerge through characteristic D-shaped holes in the bark. Eggs are deposited on the bark in late spring or early summer. Young larvae bore directly through the bark to the phloem. There they excavate winding mines in the inner bark and outer wood of the main trunk and larger branches. These mines run back and forth in all directions (fig. 119), and in the event of heavy attack, they girdle and kill the trees. Attacks usually begin in the tops of trees and are extended downward as the trees continue to weaken *(510)*.

Control under forest conditions is usually impractical. A chalcid wasp, *Phasgonophora sulcata* Westwood, is the beetle's primary parasite, accounting for 10 percent of the host in Wisconsin *(511)*. Except for management practices that maintain or promote tree vigor, such as watering and fertilizing valuable shade trees, there is little that can be done to protect trees from attack.

The **bronze birch borer**, *A. anxius* Gory, apparently occurs throughout most of the range of birch in Canada and the United States. Various birches, especially paper and yellow, are preferred hosts. The adult is deep green-bronze and about the same size and shape as the adult of the twolined chestnut borer. There are coppery reflections on the front of the pronotum; the front of the head is greenish in the male and copper-bronze in the female. Full-grown larvae are slender, flattened, about 25 mm long, and have two spines at the posterior end.

Adults begin to emerge in late May or early June and continue until August, depending on locality, and they feed on leaves for about 3 weeks before egg laying begins. Eggs are deposited singly or in small groups beneath loose curls of bark and in cracks and crevices in the bark, mostly on unshaded parts of the tree. Young

Courtesy Pa. Bur. For., For. Pest Manage., Middletown

Figure 119.—Galleries of the twolined chestnut borer, *Agrilus bilineatus*.

larvae bore directly through the bark to the cambium area. There they excavate galleries between the bark and wood, with occasional side trips into the xylem to molt and then to spend the winter. The galleries wind back and forth, usually across the grain of the wood. Mature larvae construct oblong cells in the wood or thick bark in which they spend the winter and pupate in the spring. Larvae of all sizes and ages have been found in infested trees during the winter, but the only ones capable of developing to adults were those which became mature before winter set in and were later subjected to subfreezing temperatures. In the North, 2 years are required to complete the life cycle; in the South there is one generation per year. The biology of the bronze birch borer in New Brunswick has been reported *(62)*.

The bronze birch borer prefers weakened or injured trees *(765)*. Damage may be extremely severe in stands of such trees. Weakened residual trees following logging, and individual shade and ornamental trees weakened by drought or other factors, are often seriously injured. Enormous volumes of birch suffering from dieback have been killed in the Northeastern States and Canada.

The **bronze poplar borer**, *A. liragus* Barter & Brown, breeds in poplar in Canada and southward in the United States to Pennsylvania and Arizona. Adults are blackish with deep-green reflections and are about 7 to 12 mm long. Overmature or defective trees and young trees suddenly released by the removal of dominant trees are most often attacked; however, felled, topped, or girdled trees and trees damaged by *Saperda calcarata* Say and infected by the fungus *Hypoxylon mammatum* (Wahl) Miller are also attractive. Infestations in standing trees usually begin in the crown and move downward.

Adults are present during a period of several weeks in the summer and feed on the leaves of poplar. Eggs are deposited in bark crevices and the larvae feed in the cambial region, excavating long tunnels that zigzag back and forth in a compact manner. The larvae feed for two seasons in Ontario before becoming mature *(63)*. Woodpeckers took heavy tolls in mature larvae, pupae, and, presumably, adults in standing trees in Ontario.

Agrilus horni Kerremans occurs in Ontario and the northern tier of Eastern States, and breeds in young, apparently healthy aspen suckers, especially quaking aspen, some of which it girdles and kills. Adults are almost identical to those of the bronze birch borer except for shorter ovipositors in the females.

Eggs are deposited on the smooth bark at the base of aspen suckers. The larvae bore into the bark and tunnel downward and out along large roots, gradually working their way through the bark to the cambium region. Once here, they turn around and tunnel back toward the main stem, making spiral galleries that encircle the roots and which may be continued up the trunk for 6 to 10 cm. Pupation takes place in a cell in the center of the stem, and the life cycle requires 2 years. Damage appears to be most severe in sparsely stocked stands or in stands growing on poor sites *(937)*.

Agrilus arcuatus torquatus LeConte, the **hickory spiral borer**, has been recorded from New York, Ohio, North Carolina, and Mississippi, apparently favoring hickory and pecan, but also infesting many other hardwoods. It, or a closely related species, has been observed attacking young oaks and other hardwoods in the Piedmont of the South *(74)*. Adults are about 8 mm long. Males have a greenish-bronze head and thorax, purplish-black elytra, and brassy underparts. Females are completely bronze.

Adults appear from May to July and feed on the leaves of their host, making large irregular holes. Eggs are deposited singly on the bark surface or on terminals or twigs, usually near the base of a small shoot of the current season's growth. The larvae feed downward beneath the bark during the summer, and during the fall they sever the wood by constructing a spiral burrow. The following spring, they continue to feed beneath the bark, constructing long, irregular tunnels that deeply engrave the wood. When they are full grown, they make a second transverse spiral cut around the wood, working first toward the pith and then out again to the phloem, leaving the bark intact. Then, they mine upward in the phloem for 2.5 to 5 cm and construct pupal cells entirely within the pith. Two years are required to complete the life cycle *(159)*. This species is often very destructive of hickory seedlings in the South.

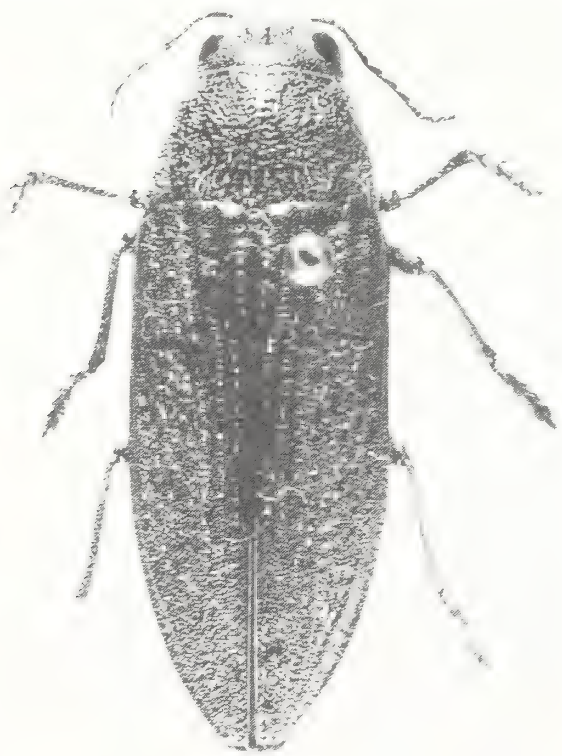
Agrilus acutipennis Mannerheim, the **spotworm borer**, has been observed attacking overcup oak in Louisiana and Arkansas *(876)*. Eggs are deposited on the bark. The larvae bore through the bark and then excavate patches of inner bark up to 12 mm in diameter. Later, they enter the wood and tunnel spirally upward in the outermost growth ring. Pupation occurs within the tunnel and the life cycle requires 2 years *(1133)*.

Damage by *A. acutipennis* results in a defect known as "grease spot." This is caused by a fungus that spreads through the wood from the tunnels. In cross section, grease spots are oval to diamond- or spindle-shaped and about 19 mm wide. Their presence in lumber greatly reduces its value. Infestations have been found frequently in river bottoms where the trees were subject to backwater flooding during the winter and spring. In such situations, entire stands of trees over 12 mm in diameter are usually infested.

Many other species of *Agrilus* also occur in eastern forests. Some of these and their more important hosts are as follows: *A. juglandis* Knull—butternut; *A. difficilis* Gory—honeylocust; *A. lecontei* Saunders and *A. celti* Knull—hackberry; *A. betulae* Fisher—river birch; *A. cephalicus* LeConte—dogwood; *A. fuscipennis* Gory—persimmon; *A. egenus* Gory—black locust; *A. otiosus* Say—hickory; and *A. masculinus* Horn—maple *(423)*.

The genus *Buprestis* is represented by a fairly large number of wood-boring species. Many seem to prefer dead and decayed wood; others are found in either weakened or perfectly healthy trees. The larvae construct tunnels in the sapwood and often the heartwood and frequently cause serious damage. The adults come in many different colors: metallic green, blue, gold, red, yellow, or orange. Often, there are many color variations and patterns within a species *(555)*.

The **turpentine borer**, *B. apricans* Herbst, long considered the most important eastern member of the genus, occurs throughout the southern coastal regions from North Carolina to Texas, and breeds in longleaf, slash, loblolly, shortleaf, and pitch pines. The adult (fig. 120) is grayish bronze with a greenish, metallic luster and is about 25 mm long. It is elliptical, somewhat flattened, and each elytron bears eight rows of large punctures. Full-grown larvae have the prothoracic plates roughened and marked above by a dark-brown Y, and they are up to 40 mm long.



Courtesy Fla. Dep. Agric. & Consum. Serv., Div. Plant Ind., photo by V. Jane Windsor

Figure 120.—Adult of the turpentine borer, *Buprestis apricans*.

Turpentine borer beetles emerge in February or March and feed for a short time on the needles in the tops of their hosts. Eggs are deposited in exposed wood containing season checks, especially at the edges of turpentine faces and on fire-scarred surfaces. The larvae tunnel in the sapwood and heartwood, construct long, narrowly oval, tortuous mines, and fill them with solidly packed, fine, granular, pitchy frass. At maturity, they form cells in which to pupate near the surface. There the adult spends the winter. About 3 years are spent in the larval stage.

The turpentine borer used to be the most destructive insect in the turpentine orchards of the South *(72, 74)*. Borer-riddled trees were weakened so severely they became subject to windbreakage. The lumber value of such trees was virtually destroyed, and gum production was seriously reduced. Attacks can be prevented or reduced by preventing the exposure of dead, dry wood to fire, logging, or other forest operations. Acid treatment to increase gum flow in naval stores operations has virtually eliminated dry faces, thereby greatly reducing the damage caused by the species.

A number of other species of *Buprestis* are also encountered in eastern forests. A few of the more common ones and their hosts are as follows: *B. striata* (F.)—adult brown with greenish reflections; it breeds in dead branches of pine, hemlock, and baldcypress. *B. lineata* (F.)—adult medium-size and dark, usually with brick-red to yellow longitudinal markings on the elytra; it attacks longleaf, loblolly, pitch, and Virginia pines. *B. rufipes* (Olivier)—adult slender and dark green, with a long, yellow basal patch and two crossbars of yellow on the elytra; infestations occur around scars on elm, beech, hickory, oak, maple, yellow-poplar, and tupelo. *B. salisburyensis* (Herbst)—adult short, oval, and green with a tooth on the inner margin of each elytron; it breeds in pitch pine. *B. maculipennis* Gory—adult rather small and blackish, with a brassy tinge and scattered yellow spots or patches on the elytra; it attacks pine and hemlock.

The genus *Chrysobothris* contains some of the most common and injurious members of the family. The larvae are all borers in the wood of both deciduous and coniferous trees. All parts of the tree are attacked, from the roots to the twigs in the crown, but the majority of attacks occur on the main trunk. The adults are small to medium size and are usually not conspicuously colored. The pronotum is usually wider than long and the scutellum is small and triangular. The elytra are rounded or angulate at the base and they strongly converge posteriorly. The legs are robust, with the femora swollen at the middle. There usually is a large tooth on each front leg. Several species are very injurious, especially to young trees weakened by drought, defoliation, or other adverse factors. The genus has been revised *(424)*.

The **flatheaded appletree borer**, *C. femorata* (Olivier), one of the commonest and best known of the flatheaded borers in North America, occurs throughout most of Canada and the United States. It attacks a wide variety of deciduous trees such as sycamore, silver maple, boxelder, black walnut, willow, white and black oaks, yellow-poplar, elm, beech, hickory, hackberry, apple, and pear. The adult is oval, flattened, dark green-bronze above, bright brassy beneath, and about 7 to 16 mm long. The elytra are marked with two wavy, depressed, light bands. Full-grown larvae are about 25 mm long.

Adults appear throughout the summer and feed on the foliage of their hosts, occasionally causing serious defoliation. Eggs are deposited under bark scales or in bark crevices on the main trunk or larger branches. The larvae bore into the bark and feed in the phloem and outer sapwood. Their tunnels are sometimes 8 cm or more long, especially in young trees. Tunnels in older trees are confined mostly to

the thick inner bark. Mature larvae construct cells in the outer wood during late summer where they spend the winter and pupate the following spring. There is one generation per year *(402)*.

The flatheaded appletree borer is especially destructive to newly planted trees and trees weakened by drought, defoliation, or other adverse factors. Young trees are often girdled and killed; larger trees are often seriously injured through the loss of large patches of bark over mined areas. Maintenance of tree vigor, wrapping the trunk with high-grade wrapping paper or burlap when trees are planted or pruned, and shading the south side of newly planted trees are recommended control practices.

The **Australianpine borer**, *C. tranquebarica* (Gmelin), also commonly known as the **mangrove borer**, occurs in southern Florida and breeds in living mangrove and horsetail casuarina trees. The adult is greenish bronze and about 12 to 17 mm long. Eggs are deposited in the spring under roughened areas of bark. The larvae feed beneath the bark until nearly full grown, and then enter the wood to construct pupal cells. Damage to ornamental or windbreak trees is often severe. The removal and destruction of infested wood during fall and winter is helpful in control.

Chrysobothris orono Frost attacks living red and jack pines in the Lake States. Eggs are laid singly on the trunk. The larvae feed in the bark during the first three instars, excavating cells and causing pitch to coagulate into large masses (fig. 121). Older larvae feed in the wood. The winter is spent in the larval stage. In the spring of the third year, the larva constructs an L-shaped cell, plugged with frass and wood chips, where pupation occurs. This species is seldom injurious, although its injury may remain in the bole as a defect after the wounds have healed.

Several other species of *Chrysobothris* also occur fairly commonly in eastern forests. Some of these and some of their more important hosts are as follows: *C.*

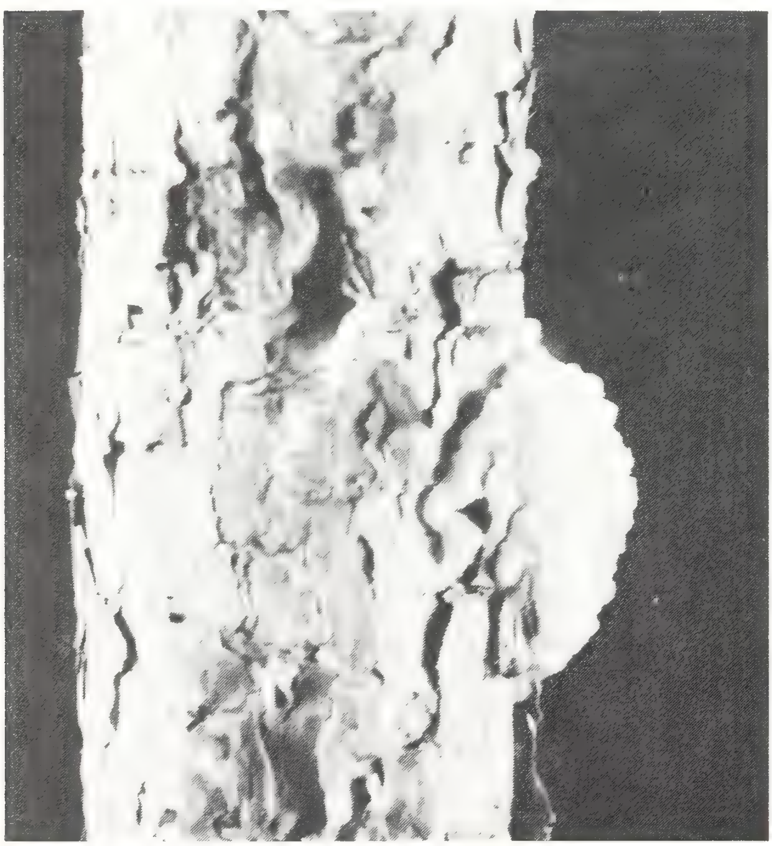


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Figure 121.—Pitch mass on red pine caused by feeding of the larvae of *Chrysobothris orono*.

pusilla Castelnau & Gory—pitch, shortleaf, and eastern white pines, white spruce, and hemlock; *C. dentipes* (Germar)—eastern white, shortleaf, longleaf, and Virginia pines, and larch (this species is reported to be strongly attracted to sawmills); *C. floricola* Gory—probably all species of pines; *C. scabripennis* Castelnau & Gory—pine, spruce, hemlock, and balsam fir; *C. trinervia* (Kirby)—white pine and spruce; *C. harrisi* (Hentz)—Virginia, eastern white, and pitch pines; *C. azurea* LeConte—white oak, dogwood, maple, basswood, birch, and willow; *C. sexsignata* (Say)—ash, red maple, walnut, hickory, beech, yellow birch, white oak, hemlock, baldcypress, and pitch pine; *C. texana* LeConte—redcedar; *C. adelpha* Gemminger & Harold—hickory and pecan; *C. viridiceps* Melsheimer—red maple, red oaks, and cherry; *C. blanchardi* Horn—eastern white, Virginia, and pitch pines, and larch; and *C. neopusilla* Fisher—balsam fir.

Chalcophora virginiensis (Drury), the **large flatheaded pine heartwood borer**, breeds in injured, dying, and dead pines and in pine stumps throughout the Eastern United States. Adults (fig. 122) are dull-black or dark-bronze beetles about 23 to 33 mm long. The thorax is broader than long, and the elytra are marked with dark or shiny elevations and rough, grayish or brassy depressions. Full-grown larvae are up to 50 mm long and the dorsal thoracic plate is marked with a Y. Eggs are deposited around scars on living areas and in bark crevices or holes in the bark of logs and stumps. Living trees may be severely damaged by larval tunnels in the wood. Pine logs left too long in the woods are also subject to severe damage. *C. liberta* (Germar) and *C. georgiana* LeConte are often found in association with *C. virginiensis*. Adults of *C. liberta* are copper or brass colored, while those of *C. georgiana* are golden bronze.

Chalcophorella campestris (Say), the **flatheaded sycamore-heartwood borer**, breeds in injured, dying, or dead sycamore, beech, oak, maple, yellow-poplar, and

F-532843

Figure 122.—Adult of *Chalcophora virginiensis*, the large flatheaded pine heartwood borer.

basswood, preferably in moist, rotting logs. The larvae resemble those of *Chalcophora virginiensis* except that they are longer, and the dorsal thoracic plate is marked with a V or U instead of a Y. This species often attacks at ax blazes and wounds and frequently riddles the wood beneath with its tunnels.

The genus *Dicerca* contains many species that breed in dead and dying trees and logs. The adults are dark-gray to brown, medium-size, metallic beetles. The head is flat, the pronotum is wider than long and grooved or ridged down the middle, the scutellum is very small, the hind coxae are strongly dilated, and the elytra are extended into taillike appendages *(915)*. A few of the more common eastern species and some of their hosts are as follows: *D. divaricata* (Say), the **divergent beech beetle**—various dead, dying, or injured hardwoods; *D. obscura* (F.)—reared from persimmon and sumac, collected on oak and hickory; *D. punctulata* (Schönherr)—various pines (often common around sawmills); *D. lurida* (F.)—hickory, American hornbeam, basswood, willow, and alder; *D. tenebrosa* (Kirby), the **gloomy borer**—pines and spruce; and *D. tenebrica* (Kirby)—poplar.

The genus *Melanophila* consists of small- to medium-size beetles, the larvae of which bore in the inner bark and outer wood of their hosts. The majority of species attack very slow-growing, dying, or recently felled trees and are of no economic importance. In the West, certain species are strongly attracted to fires and are known as "fire bugs." A key to the North American species has been published *(1092)*.

The **hemlock borer**, *M. fulvoguttata* (Harris), occurs throughout the Eastern United States and eastern Canada. Hemlock appears to be the preferred host, but it also occasionally attacks several other conifers such as eastern white pine, larch, balsam fir, and red, white, and black spruces. The adult is black with a metallic sheen and about 10 mm long. Each elytron usually bears three orange or yellow spots of equal size.

Adults appear from late spring to late summer and deposit their eggs in groups deep in bark crevices on weakened, dead, and dying trees or on logs and windthrown trees in which the cambium is still moist. The larvae bore into the inner phloem and, if conditions are not favorable for their development, they remain there until they die. Under more favorable growth conditions they penetrate to the cambium region and construct tortuous, frass-filled galleries (fig. 123). Before becoming full grown, they construct cells in the outer bark in which they spend the winter. The life cycle may be completed in 1 year in dead trees and logs. In living trees, several years may be required.

Management practices designed to promote rapid growth and good health of hemlock trees should be helpful in preventing damage by the hemlock borer. A study indicates that hemlock borer attacks are not successful until 60 percent of the roots are dead *(916)*. Rapid salvage or cutting heavily infested trees is helpful in preventing population buildup in stands weakened by windthrow or defoliation *(764)*.

Several other species of *Melanophila* also occur in eastern forests. A few common ones and their hosts are as follows: The **flatheaded fir borer**, *M. drummondi* (Kirby)—fir, larch, spruce, and hemlock; *M. notata* (Castelnau)—pines; *M. acuminata* (De Geer)—spruce, fir, pine, and northern white-cedar (adults are common around forest fires and scorched timber); and *M. aeneola* Melsheimer—pines.

The genus *Brachys* contains many species of leafminers. The larvae differ from the larvae of wood- or bark-boring species in having the prothorax only slightly

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Figure 123.—Mature larvae and galleries of the hemlock borer, *Melanophila fulvoguttata*, on the surface of the sapwood.

broader, if any, than the first abdominal segment. The adults are small and oval, and they feed on the leaves of hardwoods, sometimes riddling them with holes. The larvae mine the tissues of the leaves. *B. tesselatus* F. is very common on scrub oak in the sandhills of the southeastern Coastal Plain. Heavy annual defoliation is not unusual *(1212)*. *B. ovatus* (Weber) also mines the leaves of oak. *B. aeruginosus* Gory mines the leaves of elms.

Numerous other species of bark- or wood-boring buprestids are also encountered in eastern trees. *Ptosima gibbicollis* (Say) breeds in living redbuds. The adult is dark blue, about 6 mm long, and has two yellow spots on each wing cover. Damage is sometimes severe. *Trachykele lecontei* (Gory) breeds in dead baldcypress in Southern States. The adult is dark, ashy bronze, with black, velvety spots, and is about 9 mm long. The larvae feed in both the sapwood and heartwood, often causing a serious degrade of lumber. *Actenodes acornis* (Say) breeds in the dry heartwood of red maple, birch, beech, oak, and hickory; *Poecilonota cyanipes* (Say) breeds beneath the bark at wounds on living poplars; *P. thureura* (Say) breeds beneath the bark at wounds on willow; *Agrilaxia flavimana* (Gory) breeds in the small branches of white oak; and *Cinyra gracilipes* (Melsheimer) breeds in the dead branches of oak and eastern hophornbeam.

Family Cerambycidae
Longhorned Beetles or Roundheaded Borers

The family Cerambycidae is one of the largest and most important of the families of wood-boring beetles. More than 1,400 species have been recorded from the United States, about 450 of which occur east of the Mississippi River *(373)*. A list of 262 species either known or believed to occur in Ohio alone was published *(682)*;

the species occurring in Georgia have been discussed *(394)*. The majority of species breed in the dead wood of trees and shrubs but many, including some of the most destructive ones, attack either slightly weakened or healthy trees and other plants. Some species are vectors of the pine wood nematode, *Bursaphelenchus xyloplilus* (Steiner & Buhrer) Nickle.

The larvae of all but a few members of the family live as borers in the tissues of trees and other woody plants. Almost no part of a tree of any age or size is immune to infestation by some species. The twigs, branches, and stems of sprouts and seedlings and the twigs of branches of mature trees are girdled and severed. The sapwood and the heartwood of large limbs and trunks of living trees are often riddled and weakened, leading to windbreakage or death. Species that feed under the bark of living trees may weaken and kill their hosts, or cause defects and stains which seriously degrade lumber value. Species that attack recently felled trees, logs, or seasoned timber also cause heavy losses. Not all species are harmful, however; many of those that attack slash, stumps, and dead and dying trees are actually beneficial because they aid in the quick removal of such waste material from the forest floor and aid in its incorporation into humus.

Cerambycid beetles are distinguished by their oblong, often cylindrical bodies, their long, usually 11-segmented antennae, and their long legs. The tarsi are five-segmented, with the fourth segment small and partly concealed by the bilobed third segment. The beetles move rapidly when disturbed and are strong fliers. Some species make squeaking noises when captured.

Cerambycid larvae (fig. 124) are distinguished by a few prominent characters. They are always fleshy, thin-skinned, white or yellowish, and more or less cylindrical or depressed. In some species, the body tapers somewhat posteriorly, but the anterior segments are never suddenly and conspicuously larger than the following ones. The body is never curved and there are no prolegs or gripping processes on the last abdominal segment. There are two overlapping, circular bands of skin between each pair of body segments, the ventral mouth parts are always about on a line with the base of the mandibles, and the tenth abdominal segment is modified into two or three small retractile lobes. These borers are the subject of numerous publications *(204, 257, 259, 742, 743, 744, 745, 746, 747, 748)*.

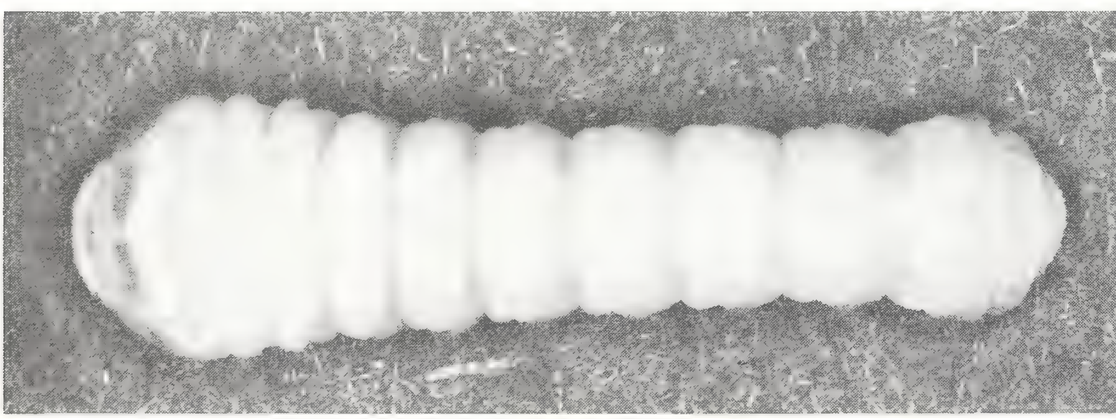

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Figure 124.—Typical larva of a roundheaded wood borer.

The **locust borer**, *Megacyllene robiniae* (Forster), one of the most important of the cerambycids, occurs in eastern Canada and throughout most of the United States wherever its host, black locust, grows. The adult ranges from 11.5 to 28 mm long. The jet-black background is marked with bright-yellow bands extending

across the thorax and wing covers, the third band on the wings being W-shaped. The legs and antennae are moderately long and yellow. Full-grown larvae are robust and about 25 mm long.

Adults are present in late summer or early fall, but are most abundant during September. They are commonly seen feeding on the pollen of goldenrod blossoms during morning hours. Later in the day, sometimes well after sunset, they are usually seen running up and down the trunks of black locust trees in search of oviposition sites. Eggs are usually deposited in rough bark crevices and around wounds on the trunks of living trees. Newly hatched larvae bore into the inner bark and construct small hibernation cells in which they spend the winter. Activity is resumed in the spring when the leaf buds begin to swell. At this time, oozing sap may be seen around larval entry holes in the trunk. The larvae soon bore into the wood where they continue to feed until mature, around mid-July. During this period they construct extensive tunnels throughout the heartwood (fig. 125A). As the larva grows, it enlarges its tunnel to the exterior, through which it pushes its granular frass to the outside and through which the adult eventually emerges. There is one generation per year *(464, 1352)*.

The locust borer has destroyed thousands of hectares of natural regeneration and plantations of black locust. Enormous numbers of older trees, especially slow-growing overtopped trees, have also been badly damaged or killed. However, vigorous dominant trees over 10 years old have seldom been killed. Infested trees are physically weakened by the larval tunnels, the smaller ones often being restricted to shrub form by repeated attacks (fig. 125B). Trees growing on poor sites are especially susceptible to attack and suffer serious damage during periods of prolonged drought.

A number of practices have been suggested for the prevention or reduction of damage by the locust borer. These include planting superior varieties of black locust, the use of mixed species in planting, the removal of old stag-headed brood trees, selection of good sites for planting, thinning and mulching of stands, and protection of young trees from fire or livestock grazing *(515, 830, 1351)*.

The **painted hickory borer**, *M. caryae* (Gahan), is widely distributed in the Eastern United States. Freshly cut hickory logs are normally preferred for breeding, but dead trees of several other hardwoods such as black locust, honeylocust, oak, hackberry, mulberry, walnut, butternut, and ash also are attacked occasionally. Hickory wood cut during the winter may be completely riddled by midsummer. The adult closely resembles the adult of the locust borer, but is slightly shorter on the average, ranging from 10 to 20 mm long. The elytra also are more tapering, the prosternum is wider than long, and the antennae of the male are longer than the body.

Adults emerge in early spring and deposit their eggs beneath bark scales on logs cut the previous winter. The larvae feed for several weeks under the bark and then bore into the sapwood and later the heartwood. Pupation occurs in the fall at the end of the larval mine behind a wad of fibrous frass. The adult, like the adult of the locust borer, emerges through the larval gallery and entrance hole. Winter is spent in the pupal stage and there is one generation per year.

Megacyllene antennatus (White), commonly known as the **mesquite borer**, breeds in mesquite and acacia in Texas and other Southwestern States. The adult is robust, brownish black, and from 12 to 30 mm long. It is marked with fine white or gray hairs and a dark spot in the center of the thorax. Eggs are deposited in crevices of the bark of recently cut wood. The larvae feed first beneath the bark and then in

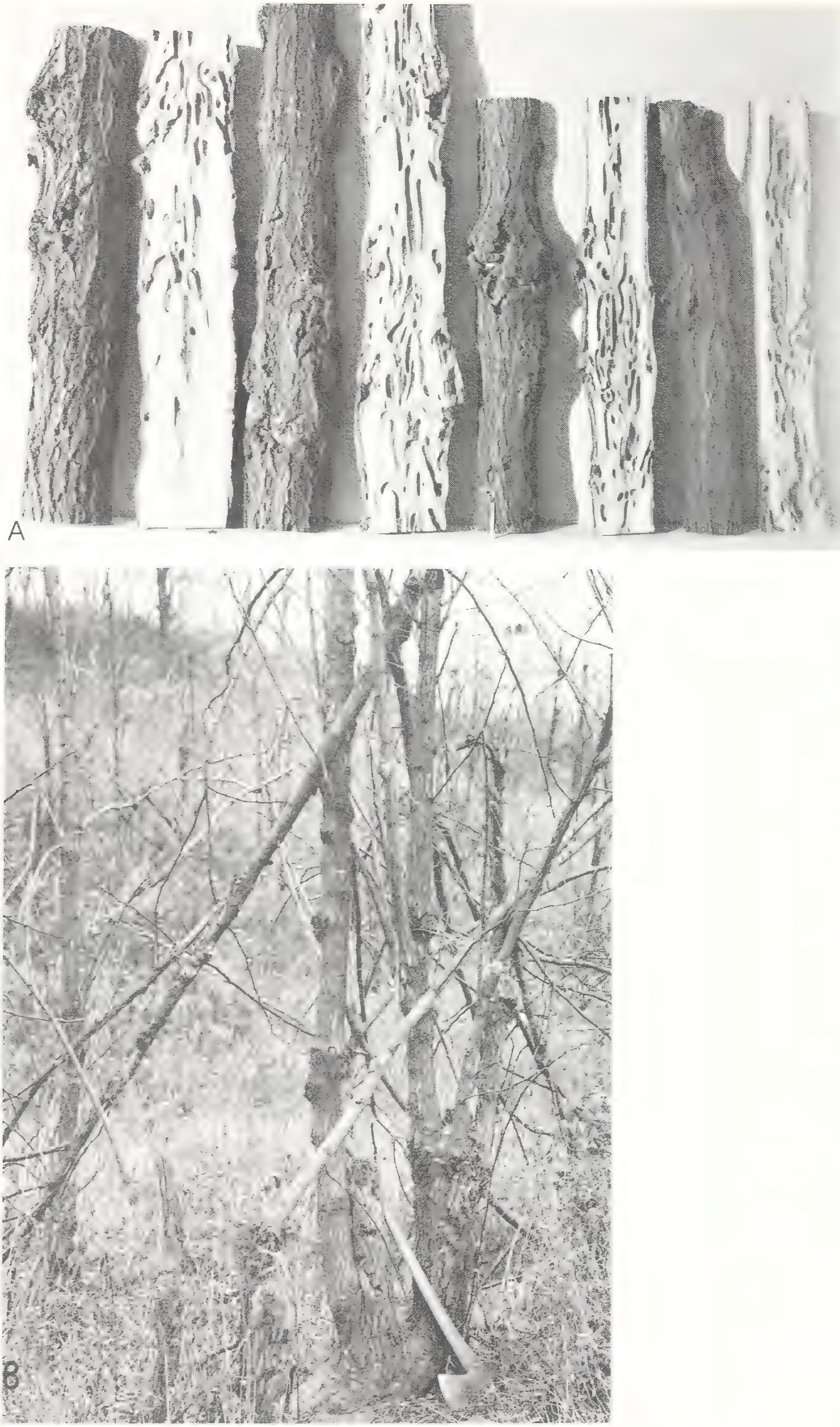

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Figure 125.—Damage caused by the locust borer, *Megacyllene robiniae*: A, larval damage in heartwood; B, damage to small trees.

the wood, excavating extensive mines and pushing quantities of frass to the outside through a hole in the bark. There are two generations a year. This species is especially injurious to mesquite cordwood. Fenceposts also are greatly weakened or destroyed. Information on control has been published *(258)*.

The **banded hickory borer**, *Knulliana cincta* (Drury), occurs throughout much of the Eastern United States where it breeds in the dead branches and trunks of a wide variety of hardwoods, such as hickory, walnut, oak, eastern hophornbeam, plum, and apple. Hickory appears to be preferred. The adult (fig. 126) is dark brown and from 16 to 30 mm long. The body is clothed with fine grayish hairs, and there is a short sharp spine on each lateral margin of the thorax. Each elytron has an oblique yellow spot near the base and two slender spines at the tip. Eggs are deposited during the summer beneath the bark or directly on the wood of recently felled, dying, or dead trees. The larvae feed beneath the bark during the remainder of the summer, deeply scarring the wood and pushing out huge quantities of granular frass through small openings in the bark. During the fall and following summer they bore into the wood and mine it extensively. Pupation occurs in the fall or spring between wads of fibrous frass at the end of the tunnel. The life cycle probably requires 2 years for completion. Cordwood, logs, posts, and rustic work are frequently seriously damaged by the species. The prompt milling and seasoning of summer-cut wood are recommended control practices.

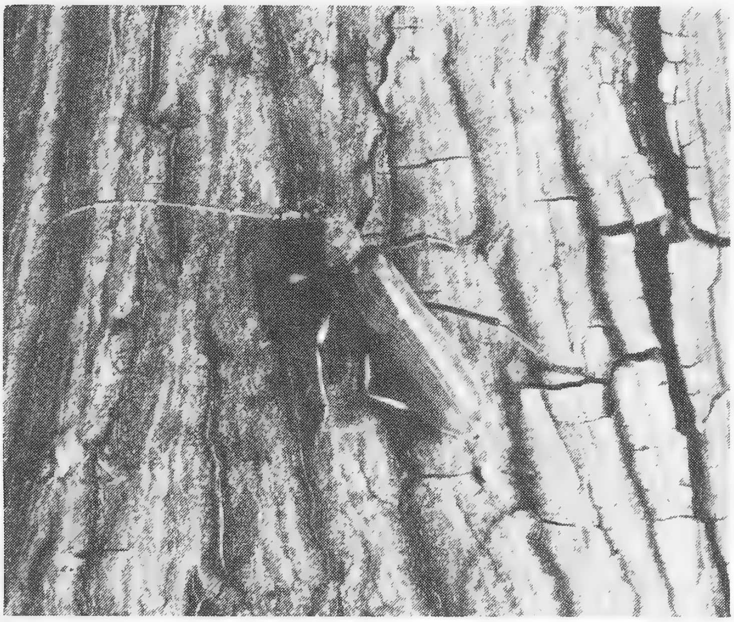

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Figure 126.—Adult of the banded hickory borer, *Knulliana cincta*.

The **cottonwood borer**, *Plectrodera scalator* (F.), breeds in the bases and roots of living cottonwood, poplars, and willows mainly in the Southern States, but is also found from New York and Michigan to Montana and Texas. The adult is 25 to 38 mm long and beautifully marked. The ground color is black, but this is obscured by patches and cross stripes of fine, pure white hairs that surround black, hairless areas (fig. 127A).

Adults appear in late spring or early summer and feed on the tender shoots of young trees. These shoots often break, shrivel, and turn black. Eggs are deposited in pits chewed in the bark at the base of the tree, at just above, or below the ground line. Trees of all sizes are subject to attack. Larvae (fig. 127B) begin boring at the

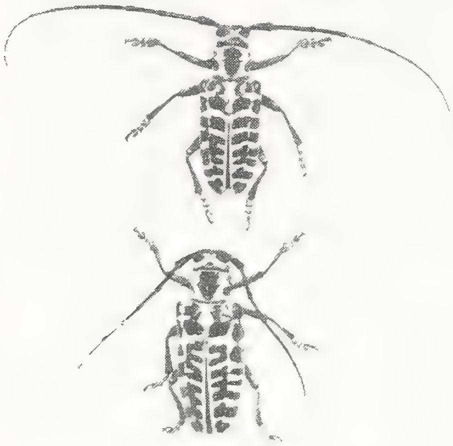

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Figure 127.—The cottonwood borer, *Plectrodera scalator*: A, adults; B, larva.

root collar and tunnel downward into the roots. Coarse, fibrous frass may be ejected from galleries at the root collar during early larval development. Part of a brood develops in 1 year and the remainder in 2 years *(878, 1130)*. Young plants may be hollowed, partially severed, or girdled at or slightly below the root collar, causing breakage *(875)*. Damage has been greatest in nurseries, young plantations, and young natural stands growing on sandy soils. Infestation counts have run as high as 27 percent in 1- and 2-year-old nurseries *(1130)*. Borer populations and losses can be reduced by using borer-free planting stock and by plowing out and destroying nursery rootstock at 3-year intervals. Insecticides can be used to control the adults before oviposition.

The **sugar maple borer**, *Glycobius speciosus* (Say), breeds in living sugar maples in southern Canada and throughout the Northeastern States, westward to the Lake States and southward through the Appalachians. The adult is robust, velvety black, and from 19 to 28 mm long. The head is clothed with fine yellow hairs; the pronotum is much wider than long, constricted at the base, and marked with two parallel yellow bands on each side. Each elytron bears five yellow bands, with those at the front forming a W-shaped design. Full-grown larvae reach a length of 50 mm *(583)*.

Eggs are deposited in bark crevices, under bark scales, or around wounds, usually during July and August. The larvae feed beneath the bark. Their tunnels run more or less across the grain and cut deep channels in the wood. The winter is spent as a larva in a chamber formed in the sapwood. The following spring, feeding is resumed, with the larva cutting a larger gallery in the sapwood. The mature larva bores deep into the wood and constructs a pupal cell at the end of its tunnel. Before entering the cell, it cuts an exit hole through which the adult emerges. During this activity, the larva pushes considerable quantities of sawdust to the outside. Pupation occurs in the spring, and the life cycle requires 2 years *(766, 1186)*.

The presence of transverse ridges or elevations on the large limbs or trunks of sugar maple, or of sawdustlike frass and moisture on the bark, are evidence of attack by the sugar maple borer. The bark over ridges is pushed outward at an angle or is broken up in the form of cracks, some of which may completely girdle the tree.

These cracked, swollen areas often resemble cankers or galls. Damage is generally most severe to shade trees or to trees growing in open stands or along streams. The larval galleries and associated stain, decay, and twisted grain cause defect and degrade in lumber sawed from infected trees *(583)*. Growing sugar maple in well-stocked groups, avoiding overgrazing, and removing and burning infested dead limbs and trees before adult emergence in the spring should be helpful in reducing losses *(1078)*. Borers in shade trees can be killed by injecting a fumigant into their tunnels or by piercing their bodies with a wire pushed into their tunnels.

The **red oak borer**, *Enaphalodes rufulus* (Haldeman), breeds in the trunks of living oaks in southern Canada and throughout the Eastern United States, west to Minnesota, Iowa, and Texas. In the Central States, red, scarlet, and black oaks are especially subject to attack. Adults are light brown with spots of lighter fine hairs, and are 14 to 28 mm in length (fig. 128). There are two small tubercles on the disk of the thorax and one triangular spot at its rear. The elytra are notched at the apex, and the sutural angles are produced into spines.

Eggs are deposited singly on living trees over 5 cm in diameter in bark crevices or beneath lichen patches during June and July. Young larvae bore directly into the phloem, and they feed there during the remainder of the summer, excavating cave-type burrows 10 to 15 mm square. The larvae spend the winter in these burrows and continue their phloem feeding in the spring. In early summer, they bore into the wood and direct their tunnels obliquely upward in the sapwood and straight upward in the heartwood for distances of 15 to 25 cm. The second winter is also spent in the larval stage with pupation occurring in the spring. The life cycle requires 2 years in the Central States with adult emergence in the odd-numbered years. Granular frass pushed out from points of attack and wet spots caused by sap leakage are evidence of attack *(539)*.

A high percentage of the large oaks in the Eastern, Southern, and Central States are attacked by this species, resulting in serious defects and serious degrade in the timber. The loss in grade can amount to 40 percent of the current tree value, which, at 1980 prices, is about $80 per 5.7 cubic meters for factory-grade lumber in terms

Courtesy J. D. Solomon, South. Hardwood Lab; Stoneville, Miss.

Figure 128.—Adult of the red oak borer, *Enaphalodes rufulus*.

of reduced quality caused by larval tunnels. About 38 percent of the oak wood used for lumber, cooperage, and veneer in the Eastern United States is affected *(321)*. Damage to upland oaks in the Central States can be reduced by poisoning borer-infested trees with a herbicide after egg laying is completed in August. Larval mortality occurs in a short time if the tree is deadened while they are still feeding in the phloem. This can be accomplished during ordinary stand-improvement operations, because the trees selected for removal in this work are the very ones most likely to be heavily infested *(538)*.

Enaphalodes cortiphagus (Craighead), the **oak-bark scarrer**, breeds in the bark of living, mature oaks throughout the Eastern United States and westward through the Ozark Mountains. White and chestnut oaks are especially subject to attack. Adults are dark brown with patches of fine, short, gray hairs on the head, pronotum, and elytra and are 16 to 27 mm in length. Eggs are deposited in bark crevices in the spring, and the larvae feed in the bark for nearly 3 years. At the end of this period they bore deeper into the bark and excavate a large pupal cell in the sapwood. This excavation usually damages several layers of annual growth of the wood, causing a large black defect and the formation of scars on the outer surface of the bark. The presence of this defect results in considerable degrade of the lumber. The related species *E. atomarius* (Drury), breeds under the bark at the bases of dead trees and in the stumps of oaks, chestnut, walnut, hickory, and hackberry in southern Canada and throughout the Eastern United States.

The genus *Goes* contains a few species that attack living hardwoods. Large tunnels constructed in the heartwood result in defects in lumber cut from infested wood. Eggs are deposited singly in oval pits chewed through the bark. Tunnels in the wood are excavated inward and upward and are kept open. Fibrous, granular frass is expelled through openings maintained at the egg scar. Life cycles vary from 2 to 5 years, depending on species.

The **white oak borer**, *G. tigrinus* (De Geer), the largest species in the genus occurs throughout the Eastern United States. White oak is its preferred host throughout most of its range, but various other oaks, and hickory and walnut are attacked occasionally. The adult is large, robust, dark brown, and from 25 to 30 mm long. It is irregularly covered with a dense coat of fine white hair, giving it a white and brown mottled appearance (fig. 129). The basal part of the elytra is roughened with small, black, elevated points; and there is a strong spine on each side of the thorax. Full-grown larvae are up to 37 mm long.

Adults emerge in May and June and feed for 1 or 2 weeks on the bark of tender twigs and leaves of oaks. Eggs are deposited in niches gnawed in the trunks of young trees, usually from 5 to 30 cm in diameter, or in the branches of larger trees. The young larvae bore directly into the sapwood. Then they tunnel upward and penetrate deep into the heartwood, excavating tunnels up to 25 mm in diameter and to 25 cm in length. Each borer makes two separate holes in the tree—a small elongate entrance hole that it keeps open for the expulsion of frass and a round hole made for the emergence of the adult. The life cycle requires from 3 to 5 years, depending on locality *(1133)*.

The white oak borer is a major pest of overcup oak in the bottom lands of Mississippi *(1134)*. Small trees down to 25 mm in diameter are attacked and seriously damaged. Trees growing on heavy clay soil with poor drainage, or where flooding is prolonged into the growing season, are frequently infested. It has been ranked as the primary pest responsible for defect in rejected staves in production of white oak cooperage in Ohio *(322)*.

Courtesy J. D. Solomon, South.
Hardwood Lab., Stoneville, Miss.
Figure 129.—Adult of the white oak borer, *Goes tigrinus*.

Goes pulcher (Haldeman), the **hickory borer**, occurs in southern Canada and throughout the Eastern United States and breeds in the sapwood and heartwood of the trunk and branches of hickory and pecan *(1128)*. The adult is from 17 to 25 mm long. Its body is dark brown, covered with fine yellowish hair. The elytra are clay yellow with dark bands across the base and the middle. In central Mississippi, adults emerge during May and June and lay eggs singly in niches between the bark and wood on trunks 2 to 14 cm in diameter, and at heights up to 4.8 m. The young larvae bore irregularly shaped mines 1 to 2 cm wide under the bark, then extend tunnels obliquely and vertically upward in the wood 8 to 17 cm, and then turn horizontally back to near the surface. At maturity larvae reach a length of 18 to 28 mm. The adult chews a circular emergence hole through the bark at the terminal point of the larval gallery. The life cycle requires 3 to 5 years.

The borer is common in the South, but populations vary greatly from one locality to another. Hickories growing in the Piedmont area of North Carolina are particularly prone to attack by this species. Open-grown trees and those near openings within young stands are most heavily attacked.

The **oak sapling borer**, *G. tesselatus* (Haldeman), occurs from Pennsylvania southward and in the Midwest where it usually breeds in the base and roots of small oak saplings, preferably white and chestnut oaks *(158)*. Young chestnuts and serviceberry are also attacked occasionally. The adult is dull brown, 20 to 27 mm long, and its body is covered with small patches of prostrate, fine gray or yellowish hairs occasionally arranged in rows. The larvae require 3 to 5 years to complete their development. During this period they may completely hollow out the base of the tree and cause its death. Less seriously damaged trees often produce bulblike swellings around the wounds at the ground line. These trees are subject to windbreakage.

Goes pulverulentus (Haldeman), the **beech borer**, breeds in the small trunks and branches of various hardwoods such as beech, oak, elm, and sycamore throughout the Eastern United States and southern Canada *(1127)*. The adult is brown, 18 to 28 mm long, and its body is clothed with short, brownish-gray hairs. The thorax has a sharp spine on each side and the elytra are faintly barred at the middle and base with fine, pale-brown hairs. In central Mississippi, adults emerge during May and June. Eggs are laid singly in niches between the bark and wood. The niches usually are

clustered, averaging 17 per cluster. The larval boring habit is similar to *G. tigrinus*. At maturity, larvae reach a length of 20 to 30 mm. The life cycle requires 3 to 5 years.

There is a tendency for the borer to favor the less vigorous, slower growing trees. Since attack occurs only on trunks less than 12 cm in diameter and branches of larger trees, the borer cannot be termed a major pest. Infested trees are easily recognized by egg-niche clusters, sap-stained bark, dark-colored frass, and later by ragged, longitudinal, overgrown scars.

Goes debilis LeConte, the **oak branch borer**, breeds in small, living branches and terminals of oak in the Eastern United States, often causing gall-like swellings. Adults are brownish and from 11 to 19 mm long. The head, thorax, and apical half of the elytra are clothed with fine reddish-yellow hairs. The elytra are crossed by two irregular brown bands, and each basal half is mottled with grayish hairs. The life cycle requires 3 to 4 years. Infested stems become swollen and gall-like and often break or die back *(1129)*.

Many species of the genus *Neoclytus* occur in eastern forests and attack both coniferous and deciduous trees. The larvae feed first beneath the bark, then bore into the sapwood and heartwood, often completely riddling it with long mines tightly packed with frass. The adults are slender-bodied beetles of medium size with quite long legs and short and more or less clubbed antennae. The pronotum bears transverse ridges and the body is marked with transverse yellow lines.

The **redheaded ash borer**, *N. acuminatus* (F.), one of our most common wood borers, occurs generally throughout the Eastern United States and in southeastern Canada. Its hosts include nearly all dying and dead hardwoods, but chiefly ash, oak, hickory, persimmon, and hackberry. Unseasoned logs of ash, oak, and hickory with the bark intact are especially subject to heavy attack. The adult is from 6 to 18 mm long. The head and thorax are reddish; the body is light brown with the apical part of the elytra sometimes much darker. The elytra are also marked with four transverse bands of fine yellow hairs and the middle and hind legs are long and reddish.

Adults become active by mid-February in the Deep South and progressively later until May or June in the North. Eggs are deposited beneath the bark of dead, unseasoned wood. The larvae feed first beneath the bark, then they tunnel into the sapwood and often reduce it to powder. In the South there are several generations per year; in the North, only one *(1252)*.

Neoclytus caprea (Say), the **banded ash borer**, occurs in eastern Canada and throughout much of the United States. Its hosts are recorded as ash, hickory, elm, mesquite, and, rarely, white oak. In the Eastern United States, it commonly breeds in ash logs. Adults are dark brown to almost black and from 8 to 17 mm long. There is a line of fine, white or yellowish hairs on the thorax and four bands of the same material and color across the elytra. The first two bands meet, almost forming circles.

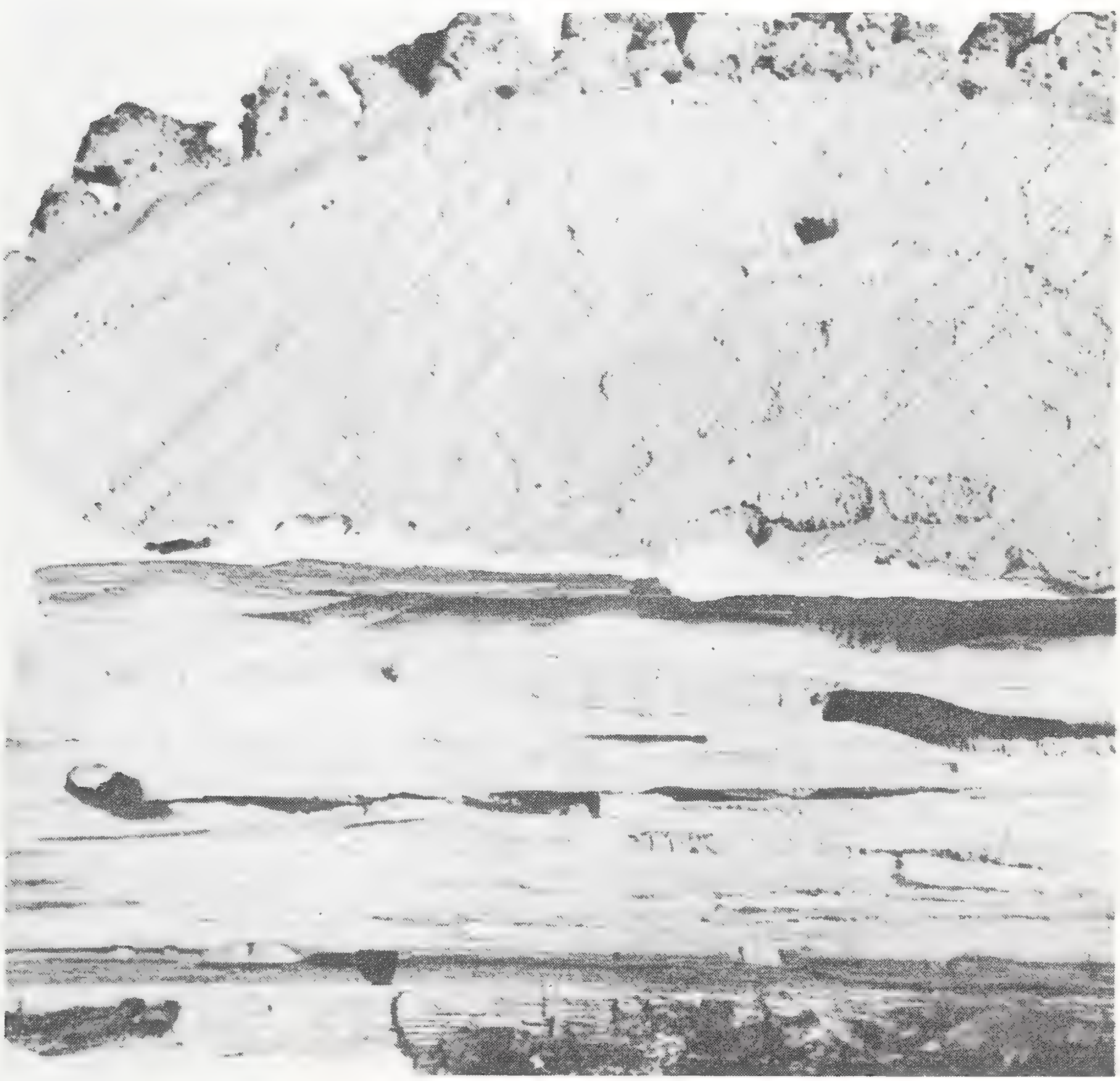
Adults emerge in early spring and fly to host material where they deposit their eggs in crevices in the bark. Ash logs cut during the winter are especially subject to attack. The larvae feed for awhile under the bark and then bore into the sapwood where they feed for the remainder of the summer. Pupation occurs in the fall, but the adult does not emerge from the wood until the following spring. There is usually one generation per year; however, if the infested material is sawed, stored, and dried out, the life cycle may require several years. Ash logs left in the woods or stored

with the bark on literally may be honeycombed with tunnels tightly packed with frass (fig. 130).

Other species of *Neoclytus* likely to be encountered in eastern forests and some of their known hosts are as follows: *N. mucronatus mucronatus* (F.) (fig. 131)—the dead branches and trunks of hickory; *N. jouteli jouteli* Davis—dead oak twigs; *N. fulguratus* Casey—dead branches of oak; *N. scutellaris* (Olivier)—elm, oak, hickory; and *N. muricatulus muricatulus* (Kirby)—larch, spruce, pine (northern coniferous forests of North America, in the East and down the Rocky Mountains to New Mexico and down the Cascades to Oregon).

The genus *Saperda* is represented in eastern forests by several important species *(401)*. Depending on the species, the larvae bore in (1) large branches or trunks of living trees; (2) small branches and produce galls; or (3) living or dead wood of dying or recently killed trees. Adults are medium size and cylindrical in form. The head is quadrate in front and very flat; the antennae are about as long as the body; the first joint of the hind tarsus is elongated; and the body is rather densely clothed with a hairy covering.

The **poplar borer**, *S. calcarata* Say, occurs throughout the United States and Canada, wherever poplars grow *(878)*. Willows are also subject to attack. In the southern latitudes, cottonwoods are the primary host; in the northern area, aspens



Courtesy Duke Univ. Sch. For.

Figure 130.—Galleries of *Neoclytus caprea*, the banded ash borer. Note that tunnels are tightly packed with granular frass.

Courtesy Duke Univ. Sch. For.

Figure 131.—Adults of *Neoclytus mucronatus mucronatus*.

are most severely damaged. Living trees, healthy or injured, are attacked. A strong preference is shown for trees that have partially succumbed to former attacks. The adult is from 20 to 28 mm long, grayish black or reddish brown, and densely clothed with fine, gray and yellow hairs (fig. 132). There are also yellowish stripes on the thorax and orange-yellow markings on the wing covers. Full-grown larvae are creamy white and about 30 mm long. Adults appear during the summer, feed on the bark of young twigs, and deposit their eggs in small slits cut in the bark, usually in the middle third of the tree. The larvae bore into the inner bark and sapwood where they later spend the winter. In the spring, they bore into the sapwood and heartwood and feed there until they are mature. Attacked trees are characterized by the presence of swollen scars and holes in the trunk and larger branches. Each larva bores an opening out to and through the bark through which frass is expelled and sap exudes. Wet areas around these holes blacken and appear varnished. The life cycle requires 3 to 5 years in the North and 2 years in the Deep South. The usual time is 3 years for most of its range. In the North, the second winter is spent as a mature larva in a cell at the end of its tunnel *(981)*.

Small trees are occasionally killed by larvae girdling beneath the bark. Larger trees are seldom killed outright, but the large larval tunnels make them susceptible to windbreakage. They literally may be riddled with tunnels. Larval openings and tunnels serve as openings for various rots, decays, and other injurious insects which may kill the tree or degrade the lumber *(878)*. Poplar plantations may be ruined and valuable shade trees severely damaged. Damage in forest stands also may be severe. In the Lake States, successful attacks appear to be concentrated in individual trees or small groups of trees unevenly distributed throughout the stand. These trees, commonly known as brood trees, are usually the larger, faster growing

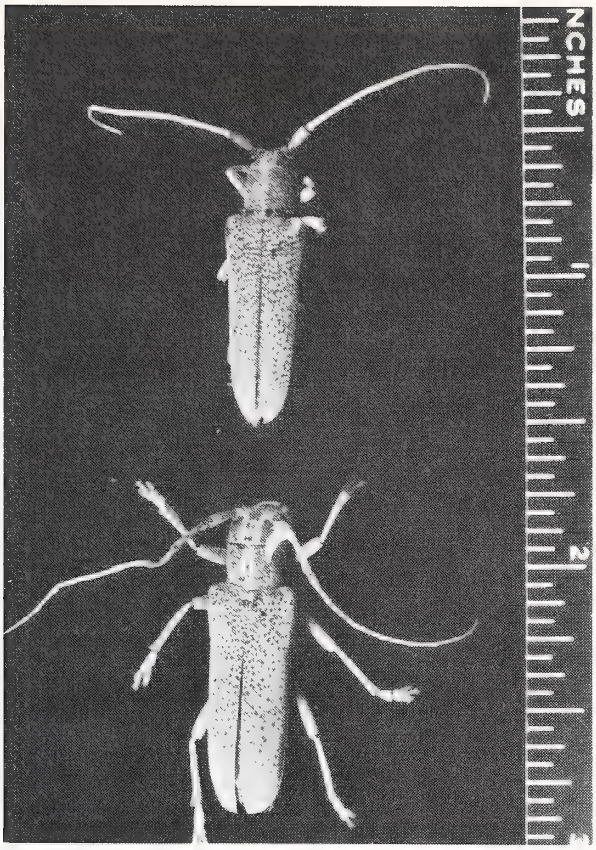


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Figure 132.—Adults of the poplar borer, *Saperda calcarata*.

trees in stands averaging between 7.5 and 28 cm d.b.h. Lake States infestations also tend to increase with a decrease in stand density.

The best practice in the management of poplar in the Lake States apparently is to maintain well-shaded stands and then clearcut them at maturity. The removal of "brood trees" should also be helpful *(388)*.

The **roundheaded appletree borer**, *S. candida* F., occurs in Canada and throughout the Eastern United States. It is most serious as a pest of apple orchards, but it also breeds in mountain-ash, hawthorn, and serviceberry. The adult is brilliantly white except for three broad, brown, longitudinal stripes extending the full length of the back, and is from 15 to 20 mm long. Full-grown larvae are creamy white and about 30 mm long *(562)*.

Adults are present from June to September and deposit their eggs in slits cut in the bark at the base of living trees. They feed on the foliage and sometimes on tender bark. The larvae feed beneath the bark for 1 year and then bore into the wood, making large excavations and riddling it. The presence of tendrils of frass on the bark or at the base of the tree is evidence of attack. Heavily infested trees may be killed in a single season. Two or more years are required to complete the life cycle. Keeping trees healthy is an effective preventive measure. Borers in high-value trees can be killed by injecting a fumigant into borer burrows.

The **linden borer**, *S. vestita* Say, occurs in the Northeastern States and Canada. Its preferred host is basswood but it also attacks poplars. The adult is reddish brown, densely covered with prostrate, fine, olive-yellow hair, and is from 12 to 21 mm long. The tips of the antennae are brown, and there are three small black spots on each wing cover. Adults feed on leaf petioles, the larger veins of leaves, and the bark of growing shoots, often killing the tips of infested branches. The larvae feed

beneath the bark and often bore deep into the wood. Unhealthy and weakened trees are most susceptible to attack.

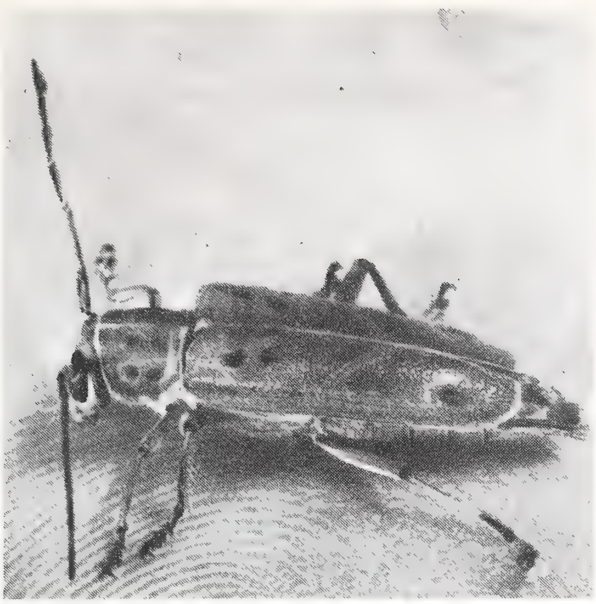
Saperda discoidea F. breeds in dead and dying hickories and butternut from New York to Louisiana and Nebraska. Hickory trees infested with the hickory bark beetle are particularly subject to attack. Adults are 10 to 17 mm long. The male is blackish with reddish legs and lines of fine, grayish hair on the thorax. The female is reddish brown or nearly black, clothed with fine, yellowish hairs, and has two spots separated by a curved bar on the elytra. Eggs are deposited in bark crevices or in holes in the galleries of bark beetles during the late spring and summer. The larvae feed gregariously beneath the bark, making extensive meandering mines. Most of the larvae mature in 1 year.

Saperda inornata Say, the **poplar-gall saperda**, breeds in the living branches and main stems of poplars and willows in the Northern and Central States *(936)*. Adults are black with fine, gray hairs and are about 12 mm long. Eggs are laid in U-shaped slits in the bark. Callous tissue forming over these slits causes the formation of globose galls. The larvae mine around the stem and then bore into wood, making galleries about 25 mm long that run parallel to the axis. The life cycle requires 1 or 2 years. Usually the infested twigs are not killed. Branches or small stems bearing numerous galls may stop growing, however, and become subject to windbreakage. Growers should avoid establishing new plantings near heavily infested stands *(1336)*.

Saperda obliqua Say, the **alder borer**, breeds in the bases of living alders and sometimes birch in the Northern and Central States. The adult is reddish brown and from 10 to 20 mm long. There are two dark bands on the thorax and four oblique bands on the wing covers. Larvae feed first beneath the bark near the base, often girdling the stem. Later they bore into the stem and tunnel upward for 8 to 15 cm. Swollen areas appear at points of attack on stems that survive, and large amounts of frass are pushed out through the openings at the egg scars. Alders in ornamental plantings are frequently killed.

Saperda fayi Bland, the **thorn-limb borer**, occurs in the Northeast and Midwest and breeds in the twigs of hawthorn causing gall-like, gnarly swellings. Adults are reddish brown and about 12 mm long. There is a white stripe on each side of the thorax that extends up to the base of the elytra. The elytra bear two white spots at the base and tip, and a single large one in between. Infested twigs are subject to windbreakage. *S. moesta* LeConte causes the formation of globose galls on the stems and branches of poplar and willow in the northern parts of the United States. Adults are dark brown to black and about 10 mm long. *S. lateralis* F. breeds in dead hickory, elm, basswood, oak, cherry, and in hickory sprouts. Adults are black or brownish black with the head, thorax, and elytra margined by broad, red lines and are about 12 mm long. The male has a tooth on each of its claws. *S. imitans* Felt & Joutel breeds in dead hickory, willow, and basswood; *S. cretata* Newman, in living apple and the limbs of living hawthorn; *S. mutica* Say, in dead willow.

The **elm borer**, *S. tridentata* Olivier, occurs in southeastern Canada and throughout the Eastern United States and breeds in dead and dying American and slippery elms. The adult is grayish or fawn colored and from 9 to 17 mm long (fig. 133). An orange-yellow or yellowish band extends from the head to the tip of each wing cover, twin black spots occur below these bands on the thorax, and there is a crossband at the base of the wing covers followed by two oblique bands. Full-grown larvae are about 12 to 15 mm long.



Courtesy Ill. Nat. Hist. Surv.
Figure 133.—Adult of the elm borer, *Saperda tridentata*.

Adults are present from late spring to late summer, and feed on young leaves and young twigs. Eggs are deposited in small holes chewed in bark crevices, usually on freshly cut logs or weakened trees. The larvae bore beneath the bark, filling their mines with fibrous frass, and completely destroying the phloem and cambium *(973)*. When they reach maturity they bore into the wood and construct cells in which to pupate. There is usually one generation per year; however, in rapidly dried wood 3 years may be needed to complete the life cycle.

Park and shade tree elms, especially the older ones and those in a weakened condition, are severely injured by this species. Affected trees tend to die very slowly, a branch at a time. The removal of infested branches is sometimes helpful in control.

Smodicum cucujiforme (Say), the **flat powderpost beetle**, occurs throughout the Eastern United States. The larvae excavate extensive meandering galleries in dry heartwood of oak and hickory. Stored lumber is frequently infested, the larvae continuing to feed in it until the wood is thoroughly riddled. The adult is small, elongate, very depressed, dull yellowish, shiny, and 7 to 11 mm long. Adults appear from June to August. Eggs are laid in crevices of exposed wood. The larvae excavate tunnels about 3 mm in diameter in the wood, tightly packing them with frass. Pupation occurs in an enlarged portion of the mine near the surface of the wood. There is normally one generation per year. In dry wood, several years may be required to complete the life cycle.

The genus *Oberea* is represented in the Eastern States by a number of slender, cylindrical beetles, the larvae of which bore in the twigs, branches, or stems of various forest, shade, and ornamental trees. These beetles are distinguished by the presence of a broad tooth on each tarsal claw.

The **dogwood twig borer**, *O. tripunctata* (Swederus), breeds in dogwood, elm, sourwood, laurel, azalea, viburnum, and various fruit trees in the Eastern United States. The adult is yellowish and about 14 mm long. The head is reddish or dark brown and there is a black spot on the scutellum. Adults appear in early spring and, after girdling the tip, the female deposits her eggs in living twigs of the host. The larva bores down the center of the twig, making a long series of holes for the expulsion of frass and cutting off portions of the twig as it bores into the green

wood. The winter is spent in the larval stage in the twig. Pupation occurs in the spring between two wads of fibrous frass. The portion of the twig containing the cell may have been girdled previously. Occasionally dogwoods and elms are seriously damaged. Cutting off and burning infested twigs might be helpful in control *(220)*.

Oberea schaumii LeConte occurs in southern Canada and south in the Eastern States to the Gulf Coast. It breeds in poplar. Adults are about 14 mm long; the thorax is yellowish or yellowish orange to black and is marked by four round, smooth spots *(935)*. The elytra are either yellowish or black. Eggs are laid in the stems and branches of suckers and seedlings; also in the twigs of saplings, poles, and large trees. The larvae feed near the pith, excavating tunnels up to 15 cm long, and boring holes to the outside for the expulsion of frass. Black, necrotic areas develop around these holes. The life cycle usually takes 3 years in northern Michigan, but a few take 2 or 4 years. Infested twigs do not die and are usually not sufficiently weakened to permit windbreakage.

Oberea myops Haldeman, the **rhododendron stem borer**, breeds in rhododendron, azalea, and mountain-laurel. The adult is pale yellow and about 12 to 15 mm long. There are two black spots on the thorax and the elytral margins are dark. Eggs are deposited in the bark of twigs between two girdles about 1 cm apart. The larva bores down the twig, into the stem, and on down to the ground. Here, it cuts off the stem, and then bores into the roots. Frass is expelled through holes along the stem and at the ground line. This species is frequently a serious pest in ornamental plantings of rhododendron. Cutting and burning infested twigs as soon as they are noticed is recommended.

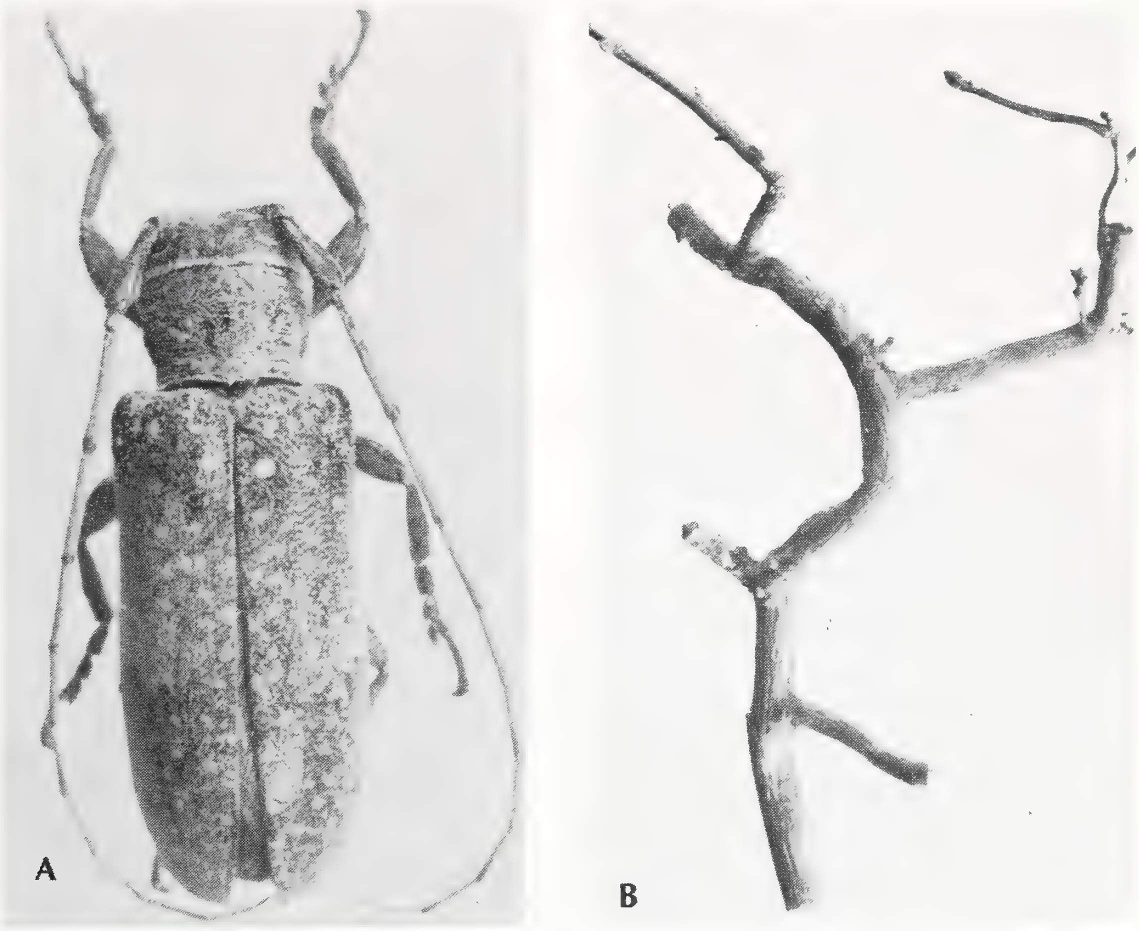
Oberea ocellata Haldeman, the **sumac stem borer**, occasionally causes serious injury in sumac plantings. Adults are about 13 to 15 mm long. The head and underside of the body are red; the thorax is red with two black spots on the disk; and the elytra are black. The female girdles the tip of the plant and then lays an egg just below the girdle. The larva bores down the stem through the pith to the roots. Here, it constructs long tunnels and feeds for two seasons. During the fall of the second year, it cuts the plant off near the ground and plugs the stub with a wad of frass. Below this plug, pupation occurs the following spring.

Oberea ruficollis (F.) breeds in the stems and roots of sassafras. Adults are pale, reddish yellow and about 18 to 20 mm long. The antennae, tibiae, and tarsi are black and the elytra are densely clothed with fine gray hairs. The feeding habits of the larvae are similar to those of *O. ocellata* except that they seldom cut off stems near the ground. Infested plants usually survive but may be badly deformed.

Other species of *Oberea* sometimes encountered are: *O. pallida* Casey—in alder in Pennsylvania; *O. ulmicola* Chittenden—in the branches of oak, elm, hickory, dogwood, and black cherry in Ohio and Pennsylvania; and *O. ferruginea* Casey—in willow canes.

The genus *Oncideres* contains several species, the females of which deposit their eggs in previously girdled terminals, twigs, or small branches of large trees, or in the stems of seedlings or sprouts. The girdled portions soon die and most of them fall to the ground. The larvae feed in the wood of this fallen material until the middle of the following summer, loosely filling their mines with frass. Pupation occurs in a cell formed by walling off a portion of the mine with fibrous frass. The adults appear in late summer or early fall and feed on the thin bark of twigs or stems. There is one generation per year in the South. In the North, many larvae do not pupate until the second year.

The **twig girdler**, *O. cingulata* (Say), is the most important eastern member of the genus. Its hosts include hickory, pecan, persimmon, elm, oak, honeylocust, hackberry, poplar, basswood, dogwood, sourwood, and various fruit trees. As a pest of pecan in the South it has been incorrectly referred to as *Oncideres texana* Horn, the **pecan twig girdler** *(741)*. Adults (fig. 134A) are grayish-brown and about 15 mm long. The front of the head is clothed with fine golden hairs; the elytra are clothed with fine gray hairs and are marked with scattered yellow spots. Full-grown larvae are up to 18 mm long.



Courtesy Duke Univ. Sch. For.

Figure 134.—The twig girdler, *Oncideres cingulata*: A, adult; B, young hickory tree deformed by repeated attacks.

Adults emerge in late summer and feed on the tender bark and tips of twigs of their host. The egg laying and larval habits are as described earlier for the genus. On heavily infested large trees dozens of branches may be girdled and severed; often, many of them hang on for long periods before dropping to the ground. Such trees are not only damaged severely but also are ragged and unattractive. Hickory seedlings are especially prone to attack and damage, often becoming distorted following attack (fig. 134B). Young pecan trees grown in plantations for timber purposes have had up to 22 percent of the terminals girdled in a single year *(662)*. Honeylocust seedlings in nurseries are also subject to serious injury. Collecting and burning infested twigs and branches during the fall or winter is an effective method of control, provided that the trees to be protected are located at some distance from heavily infested stands.

Oncideres pustulatus LeConte attacks sweet acacia, acacia, and mesquite in the Rio Grande Valley and other parts of the Southwest.

Eburia quadrigeminata (Say), the **ivory-marked beetle**, occurs throughout the Eastern United States and breeds in the dry heartwood of various hardwoods, including oak, hickory, ash, maple, honeylocust, elm, chestnut, and baldcypress. Adults are light brown, with pairs of ivory spots at the base and middle of each elytron, and are from 12 to 24 mm long. The larvae are wedge shaped, have tough, shiny skins, and are sparsely clothed with golden hairs. Mature oaks having catfaces or scars through which the larvae can gain access to the heartwood are often badly damaged. Seasoned lumber is also subject to occasional attack. The normal life cycle appears to be 2 years, but it may be considerably longer. There are records of adults emerging from flooring, doorsills, and furniture 25 years after they were placed in use.

The **twig pruner**, *Elaphidionoides villosus* (F.) occurs throughout the Eastern United States. It breeds in the twigs and branches of living hardwoods such as the oaks, hickory, maple, locust, hackberry, walnut, elm, sweetgum, and pecan. Adults are slender, elongate, brown, and are from 11 to 18 mm long. The dorsal surface is clothed with irregular patches of fine gray hairs. There are spines on the first few joints of the antennae, and the tips of the elytra are notched and bispinose.

Eggs are deposited in slits in the bark at leaf axils near the tips of twigs and small branches in late spring. Young larvae feed beneath the bark, often consuming much of the wood toward the base of the twig. Older larvae bore down the center of the stem toward the base until late in the summer. Then they sever the branch by making several concentric circular cuts from the center outward to, but not including, the thin bark (fig. 135). These branches, from 0.5 to 5 cm in diameter, break and fall to the ground with the larvae in them. The ground under heavily infested trees may be literally covered with these fallen twigs and branches. The larva returns up through the fallen branch and forms a cell between wads of fibrous frass where it pupates in the spring, or in the fall. There appears to be one generation per year. Heavily infested trees may be seriously damaged but are seldom killed. Shade and park trees may be so severely pruned that they lose much of their esthetic value. The presence of numerous dead twigs and branches hanging in the crown also detracts from their appearance. Collecting and burning infested twigs and branches in the spring before the adults emerge should be helpful in control.

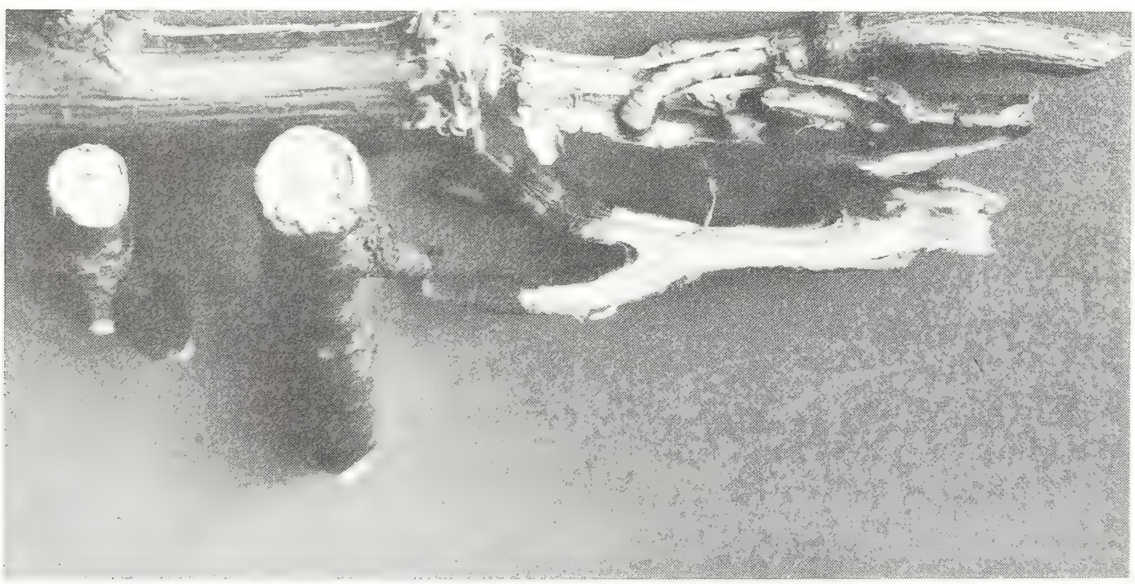


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Figure 135.—Larva of the twig pruner, *Elaphidionoides villosus*, in an oak twig. Note ends of severed twigs.

Elaphidionoides incertus (Newman), the **mulberry bark borer**, a species that closely resembles the twig pruner, breeds in the outer bark of living mulberry trees in the Eastern United States. Infestations have also been recorded in chestnut oak and pignut hickory. It does not cause serious damage.

Elaphidion mucronatum (Say), the **spined bark borer**, breeds in the dead branches of various hardwoods in the Eastern United States. Adults are dark brown, irregularly clothed with fine brown hair and are from 13 to 19 mm long. Eggs are deposited beneath bark scales, and the larvae feed beneath the bark during the first year of their lives. During the second year, they bore in the sapwood. Wood used in making rustic furniture is often damaged.

Desmocerus palliatus (Forster), the **elder borer**, breeds in elder wherever it grows in the Eastern United States. Adults are bright, metallic blue with nearly all of the basal half of the elytra yellow, and are from 18 to 26 mm long. The pronotum is much wider than long and is constricted at the apex; the wing surfaces are densely and coarsely punctured. Eggs are deposited in crevices of the bark at the base of the stem. The larvae feed in the roots and base of their host, eating out the pith and filling their mines with coarse, rather fibrous frass. The larval period lasts 2 to 3 years. Heavily infested plants may be seriously injured or killed.

Dorcaschema wildii Uhler, the **mulberry borer**, breeds in the living branches of mulberry and Osage-orange in the Southern and Central States. The adult is dark brown and from 16 to 22 mm long (fig. 136). The body is covered with fine gray hairs except for small bare punctures scattered over the surface. Each wing cover has a light-brown stripe along its outer margin.

In the Deep South, adults appear as early as mid-May. Eggs are deposited in niches chewed in the bark. Young larvae feed between the bark and wood, destroying irregular 2- to 8-cm^2 patches of cambium. After about 1 to 3 months they bore into the wood, constructing galleries that angle upward and inward for about 5 cm and then bend back toward the surface. These galleries are close together and often overlap. The winter is spent in the larval stage, and the life cycle varies from 1 to 2 years. Suppressed and fire-damaged trees are preferred, but vigorous, healthy trees are also attacked occasionally. Individual branches and even entire trees may be completely girdled and killed. Trees that recover usually have large scars on the trunk *(1126)*. The smaller but related species, *D. alternatum* (Say), is commonly found in trees infested with the mulberry borer. The larvae feed in dead and dying branches of mulberry, sometimes attacking green limbs that have been slightly injured.

Aneflomorpha subpubescens (LeConte), the **oak-stem borer**, occurs in the Eastern, Southeastern, and Central States. It breeds in small living oak and chestnut seedlings from 1 to 3 cm in diameter, and occasionally in the branches of larger trees. The adult is narrow, elongate, light brown, clothed with semierect fine brown hairs, and 17 mm long (fig. 137). There is a stout spine on each of the third and fourth segments of the female antennae, and the tips of the elytra are notched and bispinose.

Eggs are deposited at leaf bases near the tops of seedlings and sprouts. The larvae bore into the center of the stem and tunnel downward, mining out the wood as they feed. Section after section of the stem is cut off as the larvae proceed toward the base. Frass is extruded through a single row of small holes cut through the bark to the outside. During late summer the full-grown larva burrows to the base of the main stem and often into a root. Here it constructs a pupal cell between two wads of fibrous frass. The stem is usually cut off at the ground line. There appears to be one

generation per year. During certain years a high proportion of the oak seedlings in the Southeast are killed by this species.

Callidium antennatum antennatum Newman occurs throughout the Eastern United States and breeds in dead or recently felled conifers, or in lumber with the bark on. It is especially common in dead pines in the South. The adult is flattened, bright metallic blue or bluish black and from 9 to 14 mm long (fig. 138A). Male antennae are somewhat shorter than the body; the thorax is rounded, with depressions on each side of the middle; and the legs are black with large femora.

Adults appear early in the spring and deposit their eggs beneath bark scales on dead trees or on cut wood that has seasoned over winter. The larvae feed in the phloem and outer sapwood making broad, wavy tunnels in the wood (fig. 138B) and pushing large quantities of frass through small holes in the bark. Pupation occurs in the wood in long cells plugged with wads of fibrous frass. There is usually one generation per year.

This species frequently causes serious losses to improperly edged lumber in lumber yards. Rustic work and houses built of pine logs are also subject to serious damage, the wood being badly riddled and weakened and the bark so loosened that it falls away. Prompt utilization of logs, the removal of wane on sawed lumber, and kiln drying are recommended methods of control.

Callidium texanum Schaeffer, the **blackhorned juniper borer**, breeds in various conifers, preferably juniper, throughout the United States. Its habits are similar to those of *C. antennatum antennatum*. Other eastern species include: *C. schotti* Schaeffer, which breeds in the dead branches of eastern redcedar in the Midwest, and *C. violaceum* (L.), which occurs in pine, larch, and spruce in the Northeastern States.

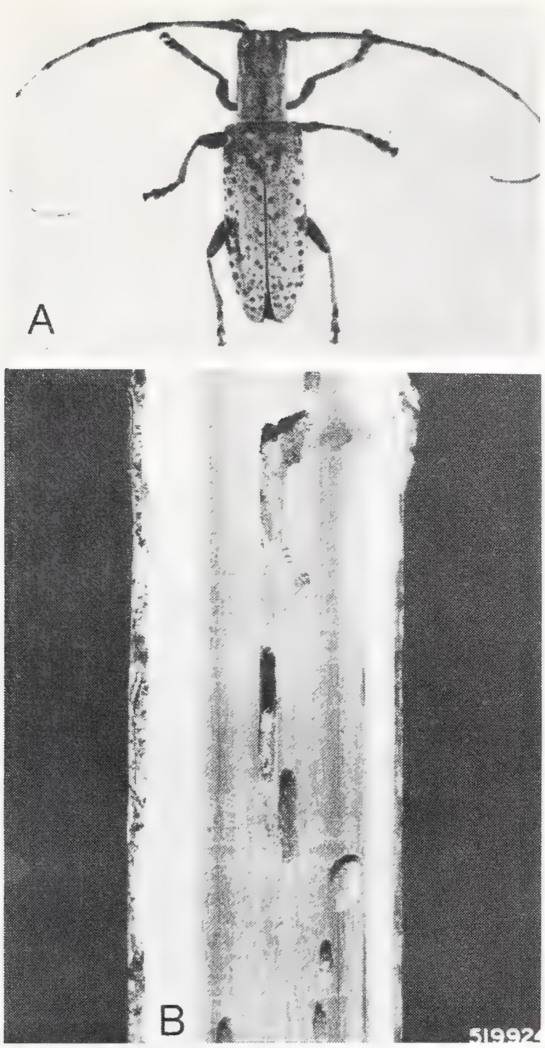
The genera *Tylocerina* and *Neacanthocinus* contain a number of species commonly known as pine bark borers *(305)*. The adults are elongate, rather flattened, and from 7 to 28 mm long. They are also usually black and mottled or striped with grayish-white or brown pubescence. The basal joints of male antennae are fringed beneath with hairs, and the ovipositor of the female is characteristically extended.

Tylocerina nodosa (F.) is a common species in the South, but is found as far north as Pennsylvania. It breeds in the thick bark of pine logs and in dying and recently killed pines. The adult (fig. 139) is gray with velvety black markings and is about 25 mm long. Male antennae are sometimes at least three times the length of the body. Eggs are deposited in pits chewed in the bark or in the exit holes of bark beetles. The larvae feed in the bark where they often compete with and destroy bark beetle broods. Pupation occurs in nestlike chambers in the bark, near the surface. There is one generation per year.

Neacanthocinus obsoletus (Olivier) breeds in recently cut pine and balsam fir in eastern North America. The adults are 7 to 14 mm long. *N. pusillus* (Kirby) is limited to the northern tier of States from Maine to Minnesota and into Alaska. The adults are 7 to 10 mm long. It has been reared from windthrown and fire-killed red and jack pines, balsam fir, and spruce.

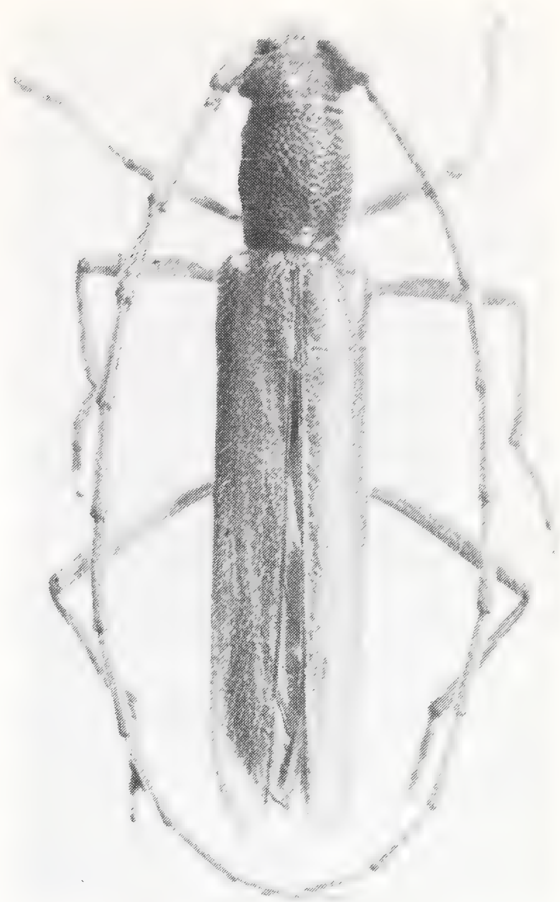
Strophiona nitens (Forster), the **chestnut bark borer**, breeds in thick, moist bark in crotches and at the base of living chestnut and oak trees. The adult is velvety black and from 10 to 15 mm long. There are golden-yellow bands on the margins of the thorax and on the elytra. Damage is seldom serious although large patches of bark are sometimes killed.

Stictoleptura canadensis (Olivier) breeds in dead pines, spruces, hemlock, and sometimes balsam fir in southern Canada and the Northern States. Living trees are



A, courtesy Duke Univ. Sch. For.
B, F-519924

Figure 136.—*Dorcaschema wildii*, the mulberry borer: A, adult; B, damage by larvae.



Courtesy Duke Univ. Sch. For.

Figure 137.—Adult of *Aneflomorpha subpubescens*, the oak-stem borer.

A B

A, F-519946; B, courtesy Duke Univ. Sch. For.

Figure 138.—*Callidium antennatum antennatum*: A, adult; B, larval galleries under the bark and in the wood.

Courtesy Duke Univ. Sch. For.
Figure 139.—Adult of *Tylocerina nodosa*, a pine bark borer.

attacked occasionally at wounds, the larvae boring into the heartwood. The adult is dull black, with the base of the elytra bright red. The upper surface is coarsely punctured, and the antennae are generally ringed with yellow. Additional eastern species of borers and their hosts include the following: *Brachyleptura vagans* (Olivier)—butternut, hickory, birch, and pine logs; *Lepturopsis biforis* (Newman)—white pine; *Pygoleptura nigrella* (Say)—pines and spruce; *Strangalepta vittata* (Swederus) and *Trachysida mutabilis* (Newman)—red spruce; *Trigonarthris minnesotana* (Casey)—hickory, elm, black cherry, and red spruce; and *T. proxima* (Say)—maple, hickory, and basswood.

Phymatodes testaceus (L.), the **tanbark borer**, breeds in the bark of dead oak trees and occasionally in stored hemlock bark in the Eastern and Central States. Adults are elongated, flattened, and are from 8 to 17 mm long. Some are brownish yellow or dark brown with lighter elytra and in some the thorax, abdomen, tibiae, and tarsi are reddish yellow and the elytra, blue. The remainder are intermediate in color. The larvae feed within or beneath the bark and pupation occurs in the sapwood. Several years may be required to complete the life cycle. Bark stored for tanning purposes is subject to heavy damage. *P. dimidiatus* (Kirby) breeds in fir, spruce, and larch in the Northern States. Adults are from 5 to 11 mm long, and dark brown, with a light-brown band across the base of the elytra. *P. varius* (F.) breeds in or beneath the dead bark of hickory and oak in Eastern and Southwestern States. The adult is light brown or dark brown to black and shiny. There are white bands on the elytra, and the adult borer is 6 to 10 mm long.

Physocnemum andreae (Haldeman), the **cypress bark borer**, breeds under the bark of girdled, felled, or dead baldcypress trees. The adult is reddish brown and ranges in length from 11 to 21 mm. There is a curved white mark on each elytron, a small tubercle near the base of the thorax, and club-shaped femora. Eggs are deposited beneath bark scales, and the larvae feed beneath the bark, excavating large mines that deeply scar the wood. Winter is spent in the larval stage, and pupation occurs in the spring. The species often causes serious losses to baldcypress trees felled or girdled during lumbering operations. Rustic work con-

structed from this wood is also subject to serious damage. Rapid utilization of girdled or felled trees and the storage of logs in ponds are effective control practices.

Physocnemum brevilineum (Say), the **elm bark borer**, breeds in the corky bark of living elm trees in southern Canada and the Eastern and Central States *(514)*. Adults are dark brown to black and from 9 to 20 mm long. The elytra are frequently bluish with three longitudinal white marks. Eggs are deposited beneath bark scales. The larvae feed in the phloem, constructing meandering, frass-packed galleries. The bark over these galleries dies and falls off. *P. violaceipenne* Hamilton breeds in the small branches of white oak in eastern Canada and the Northeastern States. Adults are 8 to 17 mm long.

Parandra brunnea brunnea (F.), the **pole borer**, occurs in central and eastern North America, and attacks a wide variety of hardwoods and conifers. Logs, poles, and other wood products in contact with the ground, such as untreated crossties and structural timbers, are also infested. The adult is flat, shiny, mahogany-brown, and is from 8 to 21 mm long. Full-grown larvae taper slightly toward the rear and are about 30 mm long.

Adults appear from July to October and deposit their eggs singly but close together, deep in either solid or decayed wood. Attacks on living trees are usually made at places where the wood is exposed such as at scars, wounds, or broken branches. The larvae feed in the wood for 3 or 4 years. Although the wood may be completely honeycombed, a covering shell of sapwood is always left intact. Pupation occurs in a cell in the wood. Many of the adults do not emerge from the wood but mate and lay eggs in the cavities in which they are working. In living wood, the wounds where the larvae gain entry will often heal over, leaving no external signs of attack. Shade trees, telephone and telegraph poles, and structural wood in moist locations or in contact with the ground are subject to severe damage. A considerable degree of protection of valuable shade trees can be provided by keeping them healthy, by the removal or treatment of exposed dead and decaying wood, and by covering pruning scars with paint.

The **cedartree borer**, *Semanotus ligneus* (F.), occurs throughout the United States. Practically all species of conifers are subject to attack, but dying and recently felled thujas and junipers are preferred. Adults are dark brown to black and from 7 to 16 mm long. The thorax is rounded and hairy, except for several bare spots on the disk. The elytra are sometimes black, but are usually dark blue with yellow or orange markings.

Eggs are deposited beneath bark scales in the spring. The larvae feed first beneath the bark, scarring the wood deeply. Then, they bore into the sapwood and occasionally the heartwood. There is one generation per year. A related species, the **firtree borer**, *S. litigiosus* (Casey), has been recorded from the Eastern United States, but is primarily western in distribution. Its hosts include several species of true firs, Douglas-fir, larch, plus several spruces. Male adults are usually all black, whereas females are black, marked with orange.

The genera *Asemum* and *Arhopalus* contain a number of species that breed in the sapwood and heartwood of the stumps of felled trees and in the lower portions of dying trees. When abundant, the larvae may destroy large portions of the sapwood. *Asemum striatum* (L.) and *Arhopalus rusticus obsoletus* (Randall) are common eastern species.

Tragosoma depsarius (L.), the **hairy pine borer**, occurs from coast to coast in southern Canada and the Northern States. It also occurs southward through the

Appalachians in the Eastern States where it breeds in various dead pines. The adult is a heavy, shiny dark-brown beetle from 20 to 40 mm long. The underside of the body is very hairy, and the elytra are ridged. Larvae are tough-skinned and have four teeth on the front of the head. Occasionally untreated crossties and poles, and timbers in contact with the ground, are seriously damaged.

Atimia confusa confusa (Say), the **small cedar-bark borer**, breeds in dying thujas, junipers, and related trees throughout the Eastern and Central States. The adult is small, stoutish, and 6 to 9 mm long. The head, pronotum, elytra, and venter are black. The dorsum is clothed with recumbent, fine gray hairs, and the elytra are notched at the apices. Adults appear in early spring and again in early fall and deposit their eggs beneath bark scales. The larvae feed entirely between the bark and wood, packing fibrous frass behind them. Pupation occurs in cells in the sapwood. The winter is spent as larvae or as adults. Rustic work constructed from improperly seasoned thuja and juniper is subject to attack and serious damage. The bark over damaged areas dries and peels off.

Aneflus protensus (LeConte) attacks living mesquite in Texas and other Southwestern States. The adult is light or dark brown, has spines on the basal joints of the antennae and the tips of the elytra, and is from 25 to 32 mm long. Eggs are deposited in bark crevices at the forks of small branches. The larvae bore into the branch and hollow it out. Frass is extruded through small holes in the bark. Black, watery liquid drips from these holes and stains the foliage and ground beneath. The interior of the larval mine is always stained black. Two years are required to complete the life cycle. Infested branches and small trees are sometimes killed.

Tetropium cinnamopterum Kirby breeds beneath the bark of dead and recently felled coniferous trees, and occurs in eastern Canada and the Northeastern States *(1009)*. The adult is oblong, somewhat flattened, brown to blackish, and about 12 mm long. The eyes are completely divided into upper and lower lobes. The larvae feed gregariously beneath the bark, packing frass behind them in the mines. The shallow-bored pupal cells in the sapwood are largely removed by slabbing. There is one generation per year in the United States. This was the most common cerambycid attacking windthrown spruce in the Adirondacks following a severe windstorm in November 1950.

Neoptychodes trilineatus (L.), the **fig tree borer**, breeds in the branches and trunks of living and dying fig trees in the Southern States. Alder is also attacked occasionally. The adult is gray except for small reddish-yellow spots on the body and white stripes on the elytra, and is 18 to 25 mm long. Eggs are deposited in small holes chewed through the bark. The larvae feed at first beneath the bark and then bore into the heartwood, where they construct long tunnels. The life cycle usually requires several years. Infested branches and small trees are often killed.

Tylonotus bimaculatus Haldeman, the **ash and privet borer**, breeds in a wide variety of deciduous trees and shrubs, preferably ash and privet, in the Eastern and Central States. Adults are dark brown and from 10 to 18 mm long. There are light spots on the wing covers and a median line and two small, shiny spots on the thorax.

Eggs are deposited at the base of privet plants and beneath bark scales on living and dying ash trees during early summer. Young larvae feed in the phloem; later they penetrate deeper and scar the wood. Large branches of ash are usually attacked and killed before the trunk is attacked. Old, mature, and drought-ridden trees, especially those growing in parks and windbreaks, are killed gradually, branch by

branch. Privet hedges are subject to severe damage. The larval stage extends over a period of 2 years.

Encyclops caerulea (Say), the **oak-bark scaler**, bores in the outer bark of living white oaks, yellow-poplar, maple, tupelo, black ash, and pignut hickory in the Eastern States. Dry scales peel off over damaged areas of bark. The adult is slender, metallic blue or green, has light-brown legs, and is 7 to 11 mm long.

Oeme rigida rigida (Say) breeds in dead and dying baldcypress and juniper throughout the Eastern United States. The adult is light to dark brown and between 16 to 20 mm in length. Eggs are deposited beneath bark scales and the larva feeds beneath the bark and in the wood, producing large quantities of granular frass. Deadened baldcypress and rustic work constructed from improperly seasoned wood are often severely damaged, causing the bark to peel off and sometimes causing destruction of pieces of wood up to 8 cm in diameter.

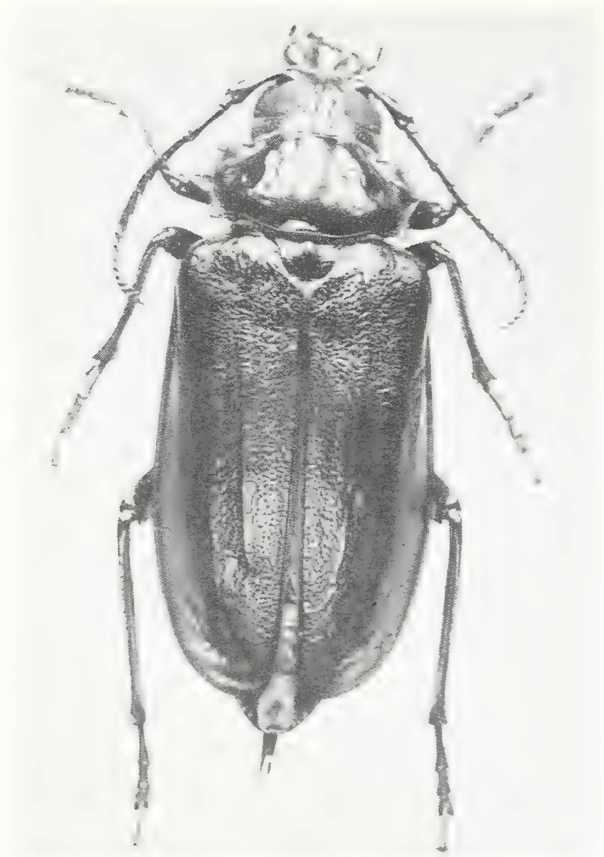
The genus *Prionus* consists of a number of species of robust, black or brownish-black, shiny beetles from 25 to 45 mm long. The antennae have from 12 to 27 segments and are heavy and imbricated in the male. There are three spines, or teeth, on each side of the prothorax. Several species are known to feed in the roots of a wide variety of living fruit, forest, and shade trees in the Eastern United States. Root rots, such as *Armillaria mellea* (Vahl ex Fr.) Kummer, and various species of secondary boring insects often attack the damaged roots and kill the trees. Mature trees growing in open stands, in well-drained gravelly soil and hillsides, in pastures, and in heavily used recreational areas are especially subject to attack. Small trees and shrubbery are occasionally killed by borers that cut off their roots at the ground line.

Prionus species have been found to be associated with declining pecan trees in Georgia and Alabama. Whether the larvae are primary or secondary invaders on pecan is unknown. There is no known adequate method for controlling the larvae or beetles *(1137)*.

The **broadnecked root borer**, *P. laticollis* (Drury), breeds in the roots of a wide variety of trees and shrubs in the Eastern United States. Mostly hardwoods are attacked, including oak, pecan, poplar, chestnut, and basswood. Infestations have also been recorded in the logs and stumps of all the above species. The adult is dark brown, shining, and 20 to 45 mm long. The head is depressed between the eyes, the antennae of the male are shorter than the body, and the base of the pronotum is as wide as the elytra. Full-grown larvae may reach a length of 75 mm. Eggs are deposited in groups on the ground and the young larvae crawl to the roots to feed. At first they feed in the bark, but soon enter the root which is completely hollowed out and occasionally severed. They move from root to root through the soil, feeding on the surfaces of smaller roots as they go and causing many injuries or wounds. Mature larvae come to within 8 to 13 cm of the soil surface in the spring and form oval, compact cells in which to pupate. The life cycle requires 3 to 5 years. This species seldom causes substantial damage in the forest.

The **tilehorned prionus**, *P. imbricornis* (L.), occurs throughout much of the Eastern United States and breeds in the living roots of oak, pecan, chestnut, pear, and various herbaceous plants. Adults (fig. 140) are dark brown, shiny, and 24 to 50 mm long. Male antennae have 18 to 22 jointed segments that overlap. Eggs are deposited in groups in the soil around the base of the tree. Larval habits are similar to those of the broadnecked root borer. The life cycle requires 3 to 5 years.

Prionus pocularis Dalman breeds in decaying pine logs and stumps throughout



Courtesy Duke Univ. Sch. For.
Figure 140.—Adult of the tilehorned prionus, *Prionus imbricornis*.

the Eastern United States. Adults are light brown, shiny, and 25 to 45 mm long. The elytra are densely punctured.

Several species of *Xylotrechus* occur in eastern forests. Adults are characterized by their moderate size, their short, filiform antennae, and a V-shaped callosity on the front of the head.

Xylotrechus quadrimaculatus (Haldeman), the **birch and beech girdler**, breeds in the branches of birch, beech, American hornbeam, maple, and alder in eastern Canada and Northeastern United States. Adults are 7.5 to 14 mm long. The thorax is black with four yellow spots; the wing covers, pale brown with faint white marks. Eggs are deposited in the axils of twigs, in bark crevices, and in healed-over injuries on branches. Young larvae feed beneath the bark, often girdling and killing the branch quickly. Later they bore toward the pith in concentric circles until the branch is almost severed. At this point, they turn and bore toward the tip, packing their tunnels with granular frass. Before reaching the tip they construct pupal cells in which they spend the winter and in which they pupate in the spring. Damaged branches up to 5 cm in diameter frequently fall to the ground during midsummer with the larvae in them. There is one generation per year.

The **gallmaking maple borer**, *X. aceris* Fisher, breeds in the trunks and branches of various maples, especially small red maples, causing the formation of galls. The adults resemble those of the birch and beech girdler, although they have fainter spots on the thorax and stronger markings on the elytra. The adults are 10 to 14 mm long. Eggs are deposited during midsummer in wounds or at the bases of small dead twigs along the trunk. The larvae bore directly into the sapwood. Later they construct tunnels in the heartwood, often completely destroying the center of the trees and causing the formation of galls or swellings about the wounds. During

the second summer of their lives, they bore either directly upward or downward and pupate in cells at the end of their tunnels. Infested trees are never killed outright but are seriously weakened, becoming subject to windbreakage.

Xylotrechus obliteratus LeConte, the **poplar-butt borer**, a serious pest of quaking aspen and other poplars in the Rocky Mountain region, also occurs in many parts of the Eastern United States. The adult is dark colored and about 10 to 18 mm long. The thorax is crossed by yellow bands at the front and rear margins; the elytra are crossed by three yellow bands—the first one oblique, the middle one curved, and the last one transverse.

Adults are present during late summer. Eggs are deposited in irregularities of the bark or exposed wood, and the larvae feed beneath the bark until fall. The following year they bore into the wood where they feed for several years, much of the time in parts of the tree below the ground line. Females continue to deposit eggs in the butts of infested trees until the wood is completely honeycombed and the tree dies or is broken by wind or ice.

Xylotrechus sagittatus sagittatus (Germar) breeds in dead conifers from eastern Canada and the Northeastern States to Florida and New Mexico. In areas where pines predominate, it is especially common. Logs, slash, and trees killed by fire or bark beetles are particularly attractive. Adults (fig. 141) are dark brown and from 12 to 21 mm long. Each elytron is marked with variable stripes of fine gray hairs—one stripe along the sutural margin, one along the outer margin, and one at the apex. The larvae feed first beneath the bark, then they tunnel deep into the wood.

Courtesy Duke Univ. Sch. For.

Figure 141.—Adult of *Xylotrechus sagittatus sagittatus*.

The **rustic borer**, *X. colonus* (F.), one of the most common of all cerambycids in the Eastern United States, feeds under the bark of almost all dead hardwoods. It occurs also in southern Canada. The adult (fig. 142) is light to dark brown and 8 to 15 mm long. Each elytron is marked with an irregular line of fine yellow hairs back of the base and three transverse bands of gray hairs—one band just behind the yellow line at the base, one back of the middle, and one at the apex. The larvae feed almost exclusively in the bark without scarring the wood *(463)*. Recently killed trees are preferred.

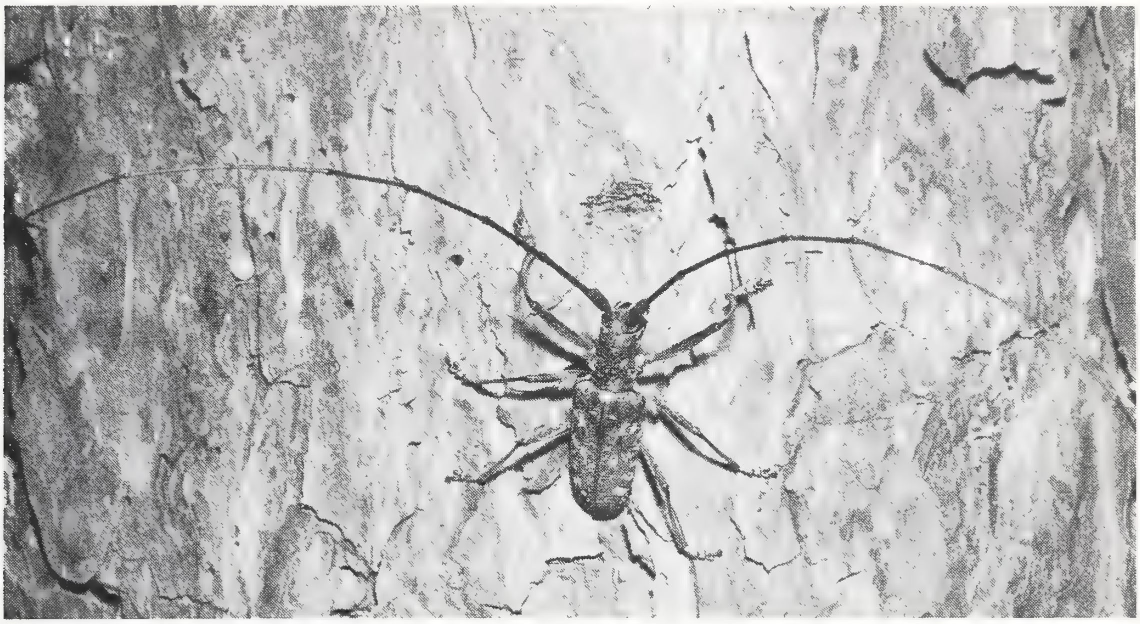
Courtesy Duke Univ. Sch. For.
Figure 142.—Adult of the rustic borer, *Xylotrechus colonus*.

Xylotrechus annosus annosus (Say) breeds in poplar and willow in eastern and central Canada and in the Northeastern and Lake States. *X. undulatus* (Say) breeds in recently cut spruce, Douglas-fir, and lodgepole pine from eastern Canada and the Lake States to Yukon Territory and central Alaska.

The genus *Monochamus* is represented by several important wood-boring species in eastern forests, all of which breed in various conifers. The larvae are commonly known as "sawyers" because of the loud noise they make while feeding. Freshly cut, felled, dying or recently dead trees are preferred. Young larvae feed on the inner bark, cambium, and outer sapwood, forming shallow excavations called surface galleries which they fill with coarse, fibrous borings and frass. As they grow older, they bore deep into the heartwood, and then turn around and bore back toward the surface, thereby forming a characteristic U-shaped tunnel. A pupal cell is formed at the outer end of the tunnel, from which the adult emerges by chewing a hole out through the remaining wood and bark. Full-grown larvae are often more

than 50 mm long. Members of this genus often cause heavy losses in windthrown or fire-killed timber, in saw logs left too long in the woods before milling, and in improperly handled pulpwood. The adults are vectors of the pine wood nematode *(1340)*. A key to the adults of the genus is available *(601)*.

The **southern pine sawyer**, *M. titillator* (F.), occurs throughout the Eastern and Southern States and breeds in recently cut, windthrown, fire-killed, insect-killed, and dying pines. The adult is mottled gray and brown, and is from 18 to 30 mm long (fig. 143). Male antennae are often 2 to 3 times as long as the body, there is a strong spine on each side of the thorax, and the elytral sutures are prolonged into sharp spines. Full-grown larvae are up to 60 mm long.



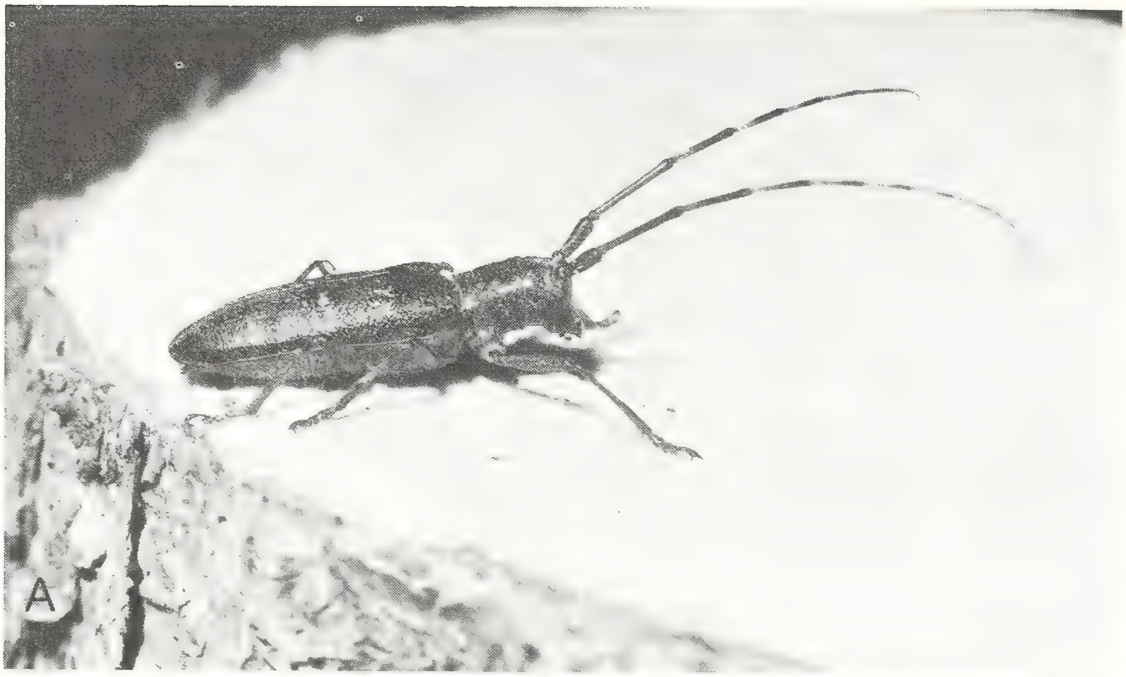
F-531253

Figure 143.—Adult of the southern pine sawyer, *Monochamus titillator*, on shortleaf pine.

In the Piedmont area of the South, adult emergence reaches a peak in April and May. However, adult activity continues until late fall and probably to some extent throughout the winter. Larval habits are as described for the genus. There are at least two generations per year in the South, with overlapping broods *(1261)*. Prompt salvage and utilization of windthrown and dead and dying trees, debarking recently dead trees, and water storage of logs will prevent attacks by this species.

The **whitespotted sawyer**, *M. scutellatus* (Say), occurs from Newfoundland to North Carolina, Minnesota, and Alaska. Eastern white pine appears to be its favorite host, but it also attacks many other conifers such as red and jack pines; balsam fir; white, black, and red spruces; and larch. The adult (fig. 144) is about 18 to 25 mm long. The male is completely shiny black except for a small, rounded white spot at the base of the elytra; females are of the same color or have the elytra mottled with white spots. Two years are required to complete the life cycle in the Lake States and Canada. Farther south there is one generation per year. Adults emerge through circular holes cut in the bark and feed for short periods on needles and tender bark of various conifers. Eggs are then deposited in slits or niches chewed in the bark, preferably near old branch scars or in wrinkled areas on logs, pulpwood, and recently killed trees *(1034, 1319)*.

The whitespotted sawyer causes heavy losses to saw logs and pulpwood in the Northern States and southern Canada. Damage to saw logs can be prevented by



Courtesy H. F. Cerezke, Can. For. Serv.

Figure 144.—Whitespotted sawyer, *Monochamus scutellatus*: A, adult; B, larvae and damage.

cutting the trees between September and early June and removing them from the woods before late June. Damage to pulpwood can be reduced by piling it in the shade of standing trees or covering the piles with layers of slash 0.3 to 0.6 m thick.

The **northeastern sawyer**, *M. notatus* (Drury), occurs in eastern Canada and in the Northeastern States, westward to the Great Lakes region, and breeds in dead and dying eastern white pine and balsam fir and in windthrown red spruce. Adults are dark brown and up to 30 mm long. The head and pronotum are irregularly clothed with fine white hairs; the elytra are covered with fine gray and white hairs arranged in the form of interrupted stripes. The female head is greatly flattened and elongated.

The **balsam fir sawyer**, *M. marmorator* Kirby, breeds in true firs in eastern Canada and the Northeastern States, west to the Great Lakes region and south to

North Carolina. Adults are dark brown, marbled with irregular bands of white and yellow, and from 18 to 25 mm long. Recently felled trees are particularly attractive to them. *M. carolinensis* (Oliver) breeds in dead and dying pines in the Southeastern States. Adults are only about 17 mm long, otherwise they are very similar in appearance to those of the southern pine sawyer. The **spotted pine sawyer**, *M. maculosus* Haldeman, a common species in the Far West, also occurs in eastern forests. It breeds in dead and dying pines. Adults are dark reddish to blackish with patches of fine yellowish hair, and are about 16 mm long. The tip of each elytron is prolonged into a tooth.

Orthosoma brunneum (Forster), the **brown prionid**, breeds in decaying coniferous and hardwood logs in southeastern Canada and throughout much of the Eastern United States. The adult is light brown, flattened, and from 25 to 50 mm long. The pronotum is narrower than the elytra and has three sharp spines on each side. There are three fine, raised longitudinal lines on each elytron. The body of the larva is slightly tapering and shines with a lemon or yellowish tinge.

Eggs are deposited from June to late summer in wood that has been dead for several years, especially in wood with very high moisture content and containing decay fungi. The larvae feed for 2 to 3 years, packing their tunnels with coarse, fibrous frass. Crossties, structural timbers, poles, or other wood in contact with the ground may be severely damaged or destroyed. Damage can be prevented by keeping the wood dry or by treating it with a preservative before placing it in contact with the ground.

Stenodontes dasytomus dasytomus (Say), the **hardwood stump borer**, occurs from Virginia southward and westward and breeds in the heartwood of living hardwood trees such as various oaks, sycamore, willow, and boxelder. Wood in contact with the ground is also attacked. The adult is a large, somewhat flattened, reddish-brown beetle from 23 to 47 mm long. The head is large and the sides of the prothorax are armed with small, fine teeth. Eggs are deposited around wounds, particularly near the base of the tree, and the larvae bore into the heartwood. They feed there gregariously for 3 or 4 years, completely honeycombing the wood. Shade trees are sometimes weakened so badly that they break and fall during storms. Crossties and other wood products in contact with the ground are also subject to serious damage.

Archodontes melanopus melanopus (L.) breeds in the roots of live and water oaks, boxelder, persimmon, and hackberry from Virginia to Florida and westward along the Gulf Coast. The adult is broad, rather flat, dark brown, and from 33 to 50 mm long. The head is distinct and rather large, and the edges of the prothorax are finely toothed. Full-grown larvae are almost 90 mm long.

Eggs are deposited at the base of young trees, just below the ground line. The larvae bore into the roots and excavate large, flattened galleries in the wood. Huge galls form on infested roots and interfere with the growth of the tree. Heavily infested trees may die and be replaced by clumps of bushlike suckers. It has been suggested that this species was largely responsible for the creation of large, comparatively barren areas of scrub oak in parts of southern Georgia and Florida.

Rhagium inquisitor (L.), the **ribbed pine borer**, occurs throughout the United States and in southern Canada, and it breeds in the inner bark of various species of dying conifers. The adult is black except for mottlings of reddish-brown or gray and is about 9 to 21 mm long. The thorax is slender and bears a spine on each side. The larvae are distinguished by their very thin, flat heads. Eggs are deposited in early spring in crevices of the bark of trees that died or were cut during the preceding

winter. Trees dead for only a short time and containing considerable amounts of moisture are preferred by the larvae. They feed entirely beneath the bark, excavating irregular galleries and packing them with fibrous frass. When they become full grown they construct oval, fibrous-edged cells in which they pupate and spend the winter as adults.

The **old house borer**, *Hylotrupes bajulus* (L.), is native to the Atlas Mountains of northern Africa *(193)*. It was introduced into North America more than a century ago. Serious infestations have occurred in the Atlantic and Gulf Coast States from Massachusetts to Texas. Spot infestations have been found as far north as Wisconsin and Minnesota and as far west as Nebraska. It breeds in dry, seasoned, coniferous sapwood. Pine and spruce appear to be preferred, but hemlock, true fir, and Douglas-fir are also attacked. The adult (fig. 145A) is a slightly flattened, brownish-black beetle from 8 to 20 mm long. The head and forward part of the body are clothed with gray hairs; the thorax has several small tubercles at the side and a black line and two black spots on the disk; and each wing cover bears either patches of gray that fuse to form two crossbands, or two whitish spots. Full-grown larvae are wedge shaped, deeply segmented, and up to 30 mm long.

F-494430, 494432

Figure 145.—The old house borer, *Hylotrupes bajulus*: A, adults; B, damage.

Eggs are deposited in fan-shaped clusters or in rows and layers in holes or tight crevices. Stacked lumber and cracks and natural checks in the wood of houses are especially subject to attack. Young larvae feed near the surface of the wood; older ones bore into the sapwood and seriously damage it with their frass-packed tunnels. The larvae seldom break through the surface of the wood. Thus, timbers so severely damaged as to be near collapse may appear from the outside to be perfectly sound. The length of the life cycle is not exactly known. In the Southern States, from 3 to 5 years may be required. In the northern parts of its range, an additional 2 to 3 years may be necessary. The length of the cycle may also vary considerably in a given building. In attics, where generally warmer temperatures prevail, adults may emerge up to 2 years earlier than those in wood in the basement.

The old house borer causes severe damage in houses and other buildings. Structural timbers (fig. 145B), framing members, and other wood parts are seriously weakened by larval mining and tunneling. Air-dried pine floor joists, plates or sills, and subflooring are apt to be damaged most severely. Other framing such as studs, stair carriages, furring strips, and roof rafters are sometimes attacked.

When an old house borer infestation is discovered, two types of remedial action are necessary: (1) repairing or correcting serious structural defects, and (2) controlling the remaining insects present in wood left in place *(870, 871, 1305).*

Chlorophorus annularis (F.) has been recovered from infested, imported bamboo at several locations in this country, and it may be established here. The adult is blackish, with green markings on the thorax and a yellow, X-shaped mark on the elytra, and is about 10 mm long. The first two pairs of legs and the inner parts of the antennae are red. Well-seasoned bamboo is mined extensively, and the mines are tightly packed with fine, powdery frass. This species is a serious pest of bamboo in India and Japan.

Superfamily Curculidnoidea
Snout Beetles

Snout beetles are a morphologically distinct group in the order Coleoptera that were formerly placed in a suborder, Rhyncophora. Adults of this superfamily have the area in front of the eyes elongated to form a rostrum or snout. But there is much variation in the extension of the area. In one family, the Scolytidae, the area is only slightly extended and might go unrecognized. The mandibles are at the end of the snout. In addition to the snout, these beetles, with a few exceptions, are distinguished by having the gular sutures united on the median line; the palpi are short, conical, and rigid. The labrum is absent.

The larvae have large sclerotized heads. The body is light colored and soft with conspicuous transverse folds or ridges in both the thoracic and abdominal segments. They are legless. When removed from their galleries (the larvae of most of the species in the superfamily are borers), they assume a characteristic C-shaped posture. Many of our most destructive forest insects belong to this superfamily. In the United States, 90 percent of all tree mortality is caused by insects; more than 60 percent of this is caused by scolytids *(1356).* Flowers, fruit, and seeds are also destroyed by various species of snout beetles. Those species that do not kill trees often severely reduce the quality of the wood because they bore into the stem, thus producing crooked logs, or holes, or pitch pockets. Other species reduce the quantity of wood either directly or by reducing the vigor of the tree by eating roots, stem, branches, or leaves.

Most of the species in this superfamily, both in terms of numbers and the amount of economic damage they produce, are found in two families: Curculionidae—the weevils—medium-size beetles with elongate snouts, no tibial spines, and the antennae inserted somewhere along the snout; and Scolytidae—the bark beetles—small, cylindrical beetles without a prominent snout, tibiae with spines, and antennae not much longer than the head.

But there are many interesting weevils that belong to a number of much smaller families. Some of these families, such as the Anthribidae and Brentidae, have been recognized as families for a long time. Other families such as the Nemonychidae, Rhynchitidae, Attelabidae, and Rhynchophoridae, have been considered, until recently, subfamilies of the family Curculionidae.

Family Anthribidae
Fungus Weevils

The fungus weevils are a relatively small family of about 90 species in North America. Few are economically important. Adults of this family have a clearly visible labrum that is not fused with the rostrum, which sets them apart from other families. Other distinguishing features are: visible and movable palpi, the pygidium is exposed, the third tarsal segment is bilobed and set into the apex of segment two, the antennae are not elbowed.

The larvae are found in dead and dying twigs and branches, and frequently in polypore fungi. *Tropideres fasciatus* (Olivier) larvae have been found in fungi associated with dead sycamore. The adults have been found on sassafras and birch. *T. dorsalis* (Thunberg) occurs in dead hemlock. *Choragus zimmermanni* LeConte has been found in fungi on dead maple and oak. The larvae of this species overwinter in the wood *(23, 1227)*.

Family Brentidae
Brentid Beetles

This family is composed of mostly tropical species. The snout of these weevils is straight and projects directly forward. The antennae are not elbowed. The thorax is longer than wide. The **oak timberworm**, *Arrhenodes minutus* (Drury), is the only tree-infesting species that occurs in the Eastern United States. It breeds chiefly in oak, beech, and poplar, and its life cycle usually requires 3 years.

Adults are dark reddish-brown with yellowish spots or bars on the elytra. They vary greatly in length: males may be from 7 to 35 mm long and females may be up to 25 mm long. The snout of the female is straight, narrow, and much longer than the head; that of the male is short and broad with large mandibles (fig. 146). The larva of this species is an exception to the legless condition usually found among weevils. Timberworm larvae have vestigial two-jointed legs.

F-519917

Figure 146.—Adults of the oak timberworm, *Arrhenodes minutus*. Male on left; female on right.

Adults are active from May through August. Both sexes are attracted to fresh wounds, and females lay their eggs in the tissue around wounds. Although most females lay their eggs on living trees, occasionally eggs are laid on dead trees, but always in wounds made before the trees died. The larvae bore through the wood, constructing galleries in all directions. The larval galleries cause serious degrade of infested trees. Occasionally much of the timber in a stand is so badly damaged that it is unfit for cooperage *(169)*.

Family Nemonychidae
Pine-Flower Weevils

This small family is represented in the West by the genus *Diodyrhynchus* and in the East by the genus *Cimberis*. These weevils are characterized by having a

functional labrum, labium, and palpi. The gular suture is double, and the antennae are straight. On the apex of the tibia there are two spines *(1227)*. Adults are usually dull red, less than 5 mm long, and have flat snouts that are about as long as the thorax. They feed on the staminate flowers of various conifers. The eggs are laid in staminate flowers and under bud scales on dead shoots where the larvae develop. *C. pilosus* (LeConte) is found in Virginia pine and *C. elongatus* (LeConte) in jack pine *(547, 1200)*.

Family Rhynchitidae
Rhynchitids

Members of this family can be distinguished by the absence of the labrum; the palpi are short and rigid; the antennae are straight, 11-segmented including a distinct 3-segmented club. The prothorax is not margined, and the elytra generally cover the abdomen. The mandibles are flattened and toothed on both the inner and outer margins. There is a single small spur on the apex of the tibiae.

There are two genera with species commonly found in the forest: *Pselaphorhynchites* with larvae that develop in dead twigs, and *Eugnamptus* with larvae that mine dead leaves. The adults of *P. aeratus* (Say) are black with a brassy or coppery cast. They are 2.1 mm to 2.8 mm long. It has been reported from most States and southern Canada in the east. Oak and willow are the major hosts reported. *P. cyanellus* (LeConte) is a larger species (2.3 mm to 3.5 mm) with a more northern distribution: southern Canada west to Alberta and Saskatchewan and south to Pennsylvania, Ohio, and Illinois. This species is also black, but has a distinct bluish cast. The antennae and tips of the legs may be paler. Adults have been collected on willow, birch, and oak *(519)*. Species of *Eugnamptus* differ from *Pselaphorhynchites* by having the pygmidium covered by the elytra. They are more slender, longer weevils. Adults of *E. collaris* (F.) are 3.5 mm to 4.7 mm long. The weevils are predominantly bluish black and red, but an entire array of color varieties have been described and named. Hickory and butternut have been reported as hosts. *E. striatus* LeConte eats hickory and walnut. An adult may be from 4.5 mm to 5.0 mm long, have a red head and thorax, and black elytra. Other species attack oak, sumac, and dogwood *(670, 983)*.

Family Attelabidae
Leaf-Rolling Weevils

Four or five species of this small family can be found on eastern trees and shrubs. This family is closely related to the Rhynchitidae but can be distinguished from it by the absence of teeth on the outer margins of the mandibles, and also by the two large spurs on the inner margin of the front tibiae.

The species most likely to be encountered are *Homoeolabus analis* (Illiger) and *Attelabus bipustulatus* F. on oak, hickory, and walnut; *A. nigripes* LeConte on sumac; and *Himatolabus pubescens* (Say) on alder and hazelnut.

The interesting thing about this group of weevils is the preparation the females make for the larvae. When an egg is to be laid, the female chews a slit in a leaf blade on both sides near the petiole. She then lays an egg near the tip of the leaf. The slits at the base permit her to fold the leaf along the midrib and then to roll it toward the petiole, enclosing the egg in a neat leaf cylinder. The petiole is then partially chewed through so that the leaf wilts and eventually falls to the ground. The larva develops in the leaf roll, and pupates either there or in the ground. There may be more than one generation a year *(454, 520, 670)*.

Family Curculionidae
Weevils

This family is reported to contain more species than any other in the animal

kingdom *(625)*. More than 35,000 have been described worldwide, 2,500 in North America *(670)*. With a few exceptions, the weevils are vegetarian; some are gall makers. Many are wondrously disguised, with cryptic color and form to mimic other insects, bird droppings, or buds. In many cases, the technique of deception is enhanced when disturbed weevils remain motionless for a long time or feign death and fall to the ground.

Some of our most destructive agricultural pests belong to the Curculionidae: the cotton boll weevil, the alfalfa weevil, and the grain weevils. Foresters have practically stopped planting eastern white pine in the Northeast because of the white pine weevil.

With such a large number of entities involved, the interpretation of the systematics of the family presents great difficulties, and authorities are not always in agreement. The sequence of species used here closely follows that of "Curculionidae of America North of Mexico" *(670)*.

There are five subfamilies of "broadnose" weevils that are characterized by short, broad snouts, and an oval depression on the face of the mandibles that marks the position of a pupal cusp. Many species of this group have larvae and pupae that are subterranean. The cusp is thought to assist adult emergence. These larvae eat roots. Consequently, those species that feed on the roots of woody plants are of concern to foresters and nurserymen. A disproportionately large number of the most common and economically important of these weevils have been introduced from Eurasia.

The **arborvitae weevil**, *Phyllobius intrusus* Kono, is a Japanese species first recorded on nursery stock in Rhode Island in 1947. It is now known to occur in the other New England States as well as New York, New Jersey, and Pennsylvania. It feeds on many varieties of arborvitae, northern white-cedar and eastern redcedar. Damage in nurseries as a result of root pruning may be severe when populations build up over a number of years.

Adult weevils are 5.1 to 6.3 mm long, black and covered with minute, light metallic-green scales and hairs. The legs and antennae are more sparsely covered.

Eggs are laid in the soil during May and June. The larval period usually extends through the winter, but some individuals overwinter as pupae. The weevil pupates among the roots in an earthern cell that may be as deep as 25 cm. Adults begin to emerge about mid-May *(663)*.

The arborvitae weevil is destructive in both the larval and adult stages but primarily in the larval stage. Damage in nurseries may be severe where infestations occur over a period of many years. In severely infested areas, well over 200 larvae may be found feeding on the roots of a single plant. This results in severe root pruning.

Phyllobius oblongus (L.), the **European snout beetle**, was first recorded in the United States at Rochester, N.Y., in 1923. It has been reported in New Jersey, Pennsylvania, and Michigan. The adults are brown and 4 to 7 mm long. They seem to prefer the leaves of sugar maple reproduction, but also eat leaves of elm, birch, cherry, and alder. Adults are present in June and July. There is one generation a year. Mature larvae overwinter in the ground.

Another introduced species (Nova Scotia, in 1884), one often associated with *P. oblongus*, is *Sciaphillus asperatus* Bonsdorff. This 5- to 6-mm-long ash gray weevil has been found as far south as Maryland, and west to Michigan. It feeds at night, primarily on sugar maple, but also on leaves of mountain and red maples, yellow birch, hazel, and hophornbeam. Because of its habit of feeding on buds, this

species has been implicated in excessive forking of sugar maple. The adults also feed on petioles and shoots. Females are active from June through September.

No males have been reported. The larvae of both these species feed on roots of plants on which the adults are found *(1089, 1343)*.

All the species of the genus *Otiorhynchus* in North America have been introduced. The two species of greatest importance to eastern trees and shrubs, the **black vine weevil**, *O. sulcatus* (F.), and the **strawberry root weevil**, *O. ovatus* (L.), are thought to have arrived early in the 19th century. Both species are parthenogenetic and flightless *(1249)*.

Adults of the black vine weevil are brownish black and 9 to 12 mm long. The prothorax is rough with rounded tubercles, each of which has a curved yellow hair. The elytra are also tuberculate with scattered tufts of metallic-yellow scales. It feeds on more than 100 plant species including yew, spruce, rhododendron, hemlock, and grape *(1249)*. The adults eat foliage, buds, and shoots, but the greatest damage is done by larvae in nursery and container plantings. In summer and fall young larvae feed on rootlets. The following spring older larvae eat the cortex of larger roots causing severe injury or death to the plant. Often the injury is not apparent until the plant is transplanted.

Adult emergence usually begins about mid-June. They are nocturnal feeders so spend the day in secluded places, frequently in the litter beneath the host plant. The eggs are laid on the ground. Larvae develop through the summer and following spring and pupate in cells down to 20 cm below the surface *(929)*. There is one generation a year *(1104)*.

The strawberry root weevil is a shiny dark-brown or black weevil. The elytra are covered with fine yellow setae. It resembles *O. sulcatus* but is smaller, about 5.5 mm long. More widely distributed than *O. sulcatus*, it has been collected in most States in the United States, including Alaska, and the provinces of Canada. Arborvitae is the preferred host of the adults, and twig girdling may cause severe injury. Hemlock is less often attacked. White, red, Scotch, and Swiss mountain pines, juniper, and Norway, white, and Colorado blue spruces have been reported as hosts. The larvae prefer the roots of hemlock *(462)*. In some places this species may have two generations a year. Occasionally, during the summer, large numbers of adults invade dwellings causing much distress, but no damage.

Because higher populations of these two weevils can cause heavy losses in nurseries and to ornamental plants, some control may have to be employed. Some insecticides, for foliar application, have been registered for these weevils.

Polydrusus impressifrons (Gyllenhal), first recorded in New York State in 1906, feeds on various hardwoods, chiefly willow, poplar, birch, apple, pear, and plum in New York and Connecticut, and possibly adjoining states. The adult is rather slender, 4 to 5.5 mm long, and uniformly light metallic-green. Eggs are deposited around scars and beneath loose flakes of bark in roughened areas. The cut ends of pruned branches and twigs of young trees are especially attractive oviposition sites. After hatch, larvae drop to the soil and feed on roots. Pupation occurs in the soil, and adults appear from mid-May to early June. They feed on developing buds, foliage, and succulent shoots. In heavy infestations, defoliation may be severe, and large numbers of stems may be girdled and killed. Damage is usually most serious in nurseries *(960)*.

Brachyderes incanus (L.), an introduced species, has been recorded from Massachusetts and Long Island. Its hosts are various species of pine. The adults feed on the needles; and the larvae, on the roots. Adults are brownish, with metallic

reflections, and are from 8 to 11 mm long. This species is often a serious pest of pine and spruce in Europe. So far, it has not been very injurious in this country.

Four species of the genus *Graphognathus*, **whitefringed beetles**, have been introduced into the Southern States *(1248)*. First observed in Florida in 1936, they now range north to Virginia and Missouri *(524)*. The adults feed on the foliage of hundreds of species of plants, including such tree species as pecan, hackberry, black tupelo, yellow-poplar, blackjack oak, hawthorn, and sassafras, but their damage is of minor importance. Most of the injury caused by this group results from larval feeding on the roots of plants. There are records of damage to tree seedlings in nurseries and fields.

The female adult (no males have been found) is dark gray and about 21 mm long. The body is densely covered with short pale hairs, with those on the elytra being somewhat longer. The forewings are fused together on the inner margins and the hindwings are rudimentary, thus the beetle cannot fly. Eggs are deposited in masses covered and held together by a sticky, gelatinous substance that hardens upon drying. They may be attached to plants or other objects at the ground line or in the soil, just below the surface. Winter is usually spent in the larval stage, and there is one generation per year *(1368)*.

The **twobanded Japanese weevil**, *Callirhopalus bifasciatus* (Roelofs), although first reported from Connecticut in 1920, was first collected in Philadelphia in 1914 *(166)*. It is now widely distributed in Eastern United States. Only females have been recorded here. They are stout weevils, 4.5 to 7 mm long, with the snout almost as wide as long. The elytra are fused, brownish gray, with two dark bands. The eggs are laid on freshly fallen leaves or leaf fragments that the female then folds and seals to make a pod. An average of three eggs is laid in each pod. They hatch in about 14 days; the larvae then burrow into the soil and begin to feed on the roots. Adults begin to appear in September.

All developmental stages can overwinter, but usually it is the adult. The adults become active in April *(11)*. The larvae and pupae have been described *(814)*. Adults eat at the leaf margin of a great variety of trees and shrubs. Reported eaten are such diverse plants as flowering dogwood, hemlock, rhododendron, oak, aralia, maple, forsythia, viburnum, and poplar.

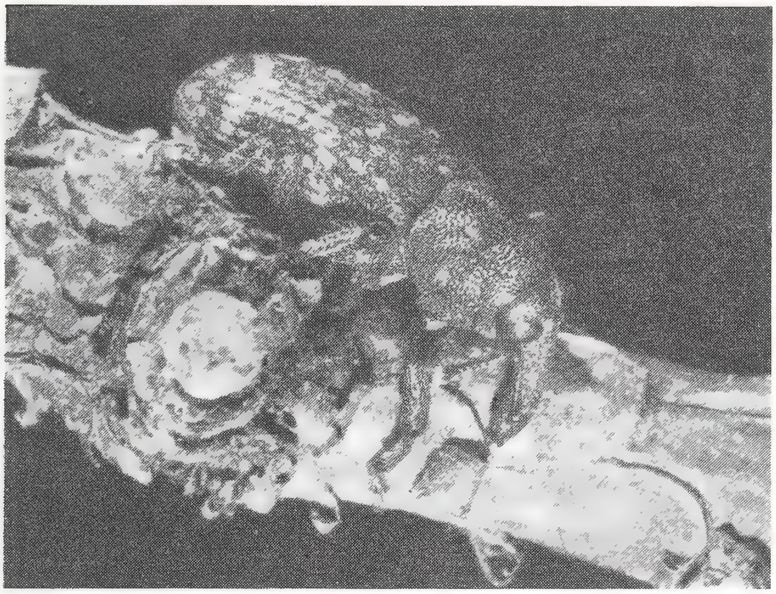
The **Asiatic oak weevil**, *Cyrtepistomus castaneus* (Roelofs), an introduced species first recorded in North America at Montclair, N.J., in 1933, is now known to occur from New Jersey to Georgia and Missouri. Oaks and Asiatic chestnuts appear to be its preferred hosts but it also attacks hickory, beech, dogwood, hazelnut, and azalea *(1209)*. Adults are black to reddish brown, irregularly clothed with minute green scales, and about 6 mm long.

The Asiatic oak weevil is parthenogenetic and has a 1-year life cycle. Apparently, eggs are laid in the soil from early July to mid-September. Larvae have been found around the roots of oak seedlings at depths of 15 cm in the soil. Winter is spent mostly in the larval stage. Adults appear in the spring and feed on the leaves of sapling oaks and chestnut. They chew in from the margins toward the midribs and devour everything but the larger veins. Later, they fly to larger trees to feed. During the fall, they sometimes invade houses in large numbers, presumably in search of hibernation quarters.

Species of the genus *Hylobius* are another group of weevils with larvae that feed primarily on or near roots. These attack conifers predominantly. Often a complex of *Hylobius* spp., *Pissodes* spp., and *Pachylobius picivorus* (Germar) will attack the

same tree. Seven species of *Hylobius* occur in North America. Keys to the adults have been published *(416, 861)*.

The **pales weevil**, *H. pales* (Herbst), is the most serious insect pest of pine reproduction in cutover pine land *(75, 938)*. It is also a problem in young reforestation areas and Christmas tree plantations. Pales weevil occurs in North America east of the Great Plains and north to Ontario. The adult is dark reddish-brown to black, 7 to 12 mm long (fig. 147). There is a patch or line of yellow-white scales on the head, and irregular patches of light scales on the elytra.



F-532346

Figure 147.—Adult pales weevil, *Hylobius pales*, feeding on loblolly pine seedling.

Pales weevil breeds in all species of pine within its range. Pitch, white, loblolly, and shortleaf pines are favored species. It has been reported from spruce, fir, juniper, larch, hemlock, northern white-cedar, and Douglas-fir.

In the North, winter is spent as adults beneath litter or as larvae in roots. In the South, adults may be active throughout the winter but are in reproductive diapause *(214)*. Depending on location, those adults in hibernation emerge from March to June. The adults are active at night and hide during the day in the soil and litter around seedlings and saplings on which they have fed. After a brief period of feeding they fly to cut, damaged, or recently dead pines *(572)*. Here they feed and mate and the females lay their eggs in the roots. Sometimes they may burrow as much as 30 cm in search of roots. The larvae feed downward in long tunnels under the bark and pupate in cells in the outer sapwood. Pupation and emergence may take place in the late summer or fall; or the larvae may overwinter, and pupation and emergence occur in early summer the following year *(133, 317, 415, 1139)*. In the North there is usually one generation a year, although some adults may live for 2 years. In the South there may be a second generation if weevils emerging in late summer or fall oviposit before winter. Adult populations peak in March through May and again in July and August *(415, 975, 1190)*.

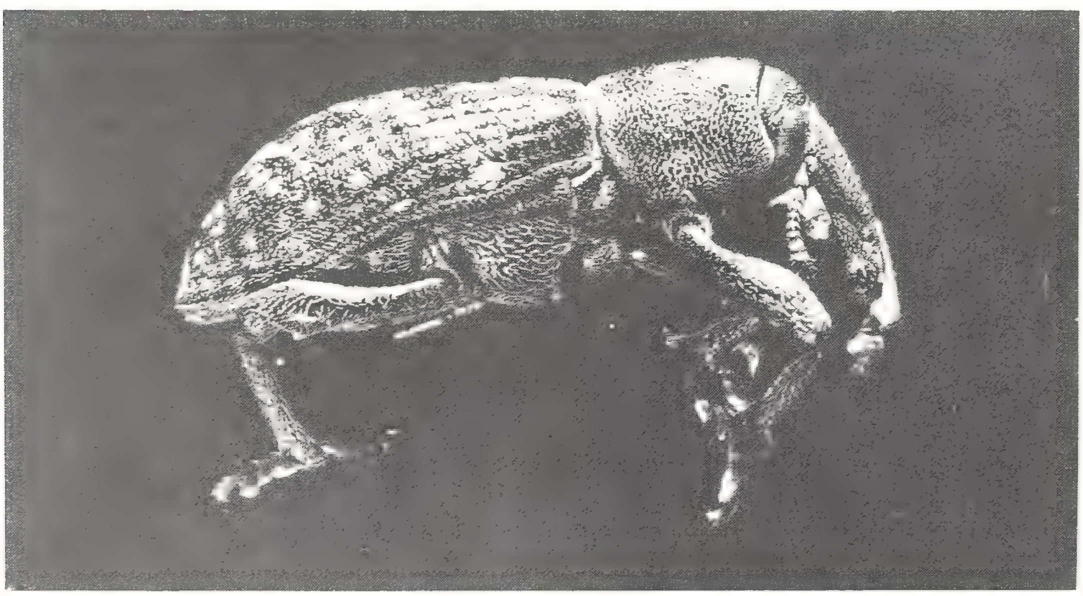
The most serious damage pales weevil does is in natural and planted seedlings in recently cutover pine areas. Weevil-caused mortality among first-year seedlings of 30 to 60 percent is not uncommon, and mortality exceeding 90 percent has been recorded *(938)*. First evidence of attack is a series of small holes chewed in the bark by adults. On lightly infested trees these may fill with oleoresin and heal over. With

heavy feeding, the damaged areas merge and may girdle and kill seedlings up to 1 cm in diameter. The seedling may be completely stripped, leaving a bare, curled stem surrounded at the base by a pile of detached needles. Adults may feed on terminals and twigs on large trees. Damage is not serious although the ends of branches may be killed. In Christmas tree plantations, twig feeding may deform trees thus lowering their value to the extent of the damage *(242)*.

Damage to young pines in cutover areas can be minimized by cultural practices. In the South, land cutover and site prepared before July can be planted the following winter without weevil damage. Weevils leave these areas before the planting season. In areas cut or site prepared in July or later, planting should be delayed 1 year. In the North and in the southern Appalachians, the waiting period should be 1 to 2 years. When delay of planting is undesirable, seedlings should be chemically treated *(934, 938, 1140, 1242)*. In the South where stands are to be established by direct seeding, no delay is necessary because weevils will have left the area before seedlings are large enough to become suitable food. In the North, a 1-year delay of direct seeding may be necessary.

There are six ways to prevent or control pales weevils in Christmas tree plantations: (1) delay planting 1 to 2 years if land was previously used for Christmas trees, (2) treat seedlings with insecticide, (3) remove stumps in spring, (4) treat stumps in spring with insecticide, (5) spray trees with insecticide from mid-August to mid-September to control weevil feeding on branches, and (6) leave a whorl of live branches on the stump to keep the stump alive and unattractive to weevils *(242, 938)*.

The **pine root collar weevil**, *H. radicis* Buchanan, breeds in the root collars of healthy pines in southern Canada from Newfoundland to Manitoba and in all of the Northeastern States south to Virginia and west to Minnesota. Of its hosts, Scotch pine seems to be the most severely damaged; but jack, red, Austrian, eastern white, pitch, and Swiss mountain pines are also attacked. The adult (fig. 148) is dark reddish-brown to black. It lacks the line or spot of pale scales on the head that *H. pales* has. The body is marked with irregular patches of white to yellow hairlike scales, and the elytra have longitudinal rows of elongated indentations. It is a larger weevil than *H. pales*—its body length ranges from 9.5 to 13.0 mm *(416)*.



F-488105

Figure 148.—Adult of the pine root collar weevil, *Hylobius radicis*.

In most localities, eggs are deposited from May to September in cavities in the inner bark at the base of the tree, or in the soil nearby *(1064)*. Peak egg laying occurs in June *(1332)*. The larvae feed downward in the inner bark of the base of the trunk and in the base of large roots below the ground line, widening their galleries as they develop. Galleries are also formed in the soil around the base. In the Lake States, the winter is spent in the larval stage. In southern Ontario, it is spent in the larval and adult stages and occasionally in the pupal stage *(417)*. Pupation occurs from June to September in cells constructed in the soil. Adults appear from August to October but do very little egg laying before entering the soil or bark crevices to spend the winter. When they emerge in the spring, they feed during the day on the bark of duff-covered branches, mate, and lay eggs. During warm evenings, they feed on the bark of the upper branches and fly to other trees. Most of these adults overwinter a second time and then are active for part of the following season *(1338)*.

Heavily infested trees may be severely injured (fig. 149). Small trees, from 2.5 to 10 cm in diameter, are most severely damaged; smaller ones are seldom attacked. The presence of pitch flows at the root collar and layers of pitch-infiltrated soil near damaged areas are evidences of infestation. A number of silvicultural practices have been suggested for reducing populations *(1327)*. These include avoidance of susceptible species such as Scotch and red pines, particularly in mixed plantings; shallow planting and maintenance of fully stocked stands. Weevils in plantations can also be reduced by pruning the lower whorls of branches and removing the litter from around the hole. This treatment was effective for up to 5 years *(1331)*. In high-value plantations, insecticide should be applied to the base of the trees in late May and June before egg laying begins *(516)*.

F-488104

Figure 149.—Damage by the pine root collar weevil, *Hylobius radicis*, at the base of a pine tree.

The **pine root tip weevil**, *H. rhizophagus* Millers, Benjamin, & Warner, is a species attacking jack pine in the Lake States *(861)*. Red, Scotch, and eastern white pines can be affected. The adult is shiny black and between 8.0 and 11.7 mm long. Dense patches of coarse scales occur on the dorsum, and the elytra bear longitudinal rows of pits containing fine setae. The adults are nocturnal. Eggs are laid mostly in June near root tips down to 75 mm. The larvae feed in roots less than 12.5 mm in diameter, tunneling from the smaller end toward the base. They complete development in June and July of the second year. Pupation occurs in cells in the roots and lasts about 20 days. Adults live 2 years. Pole-size pines in closed plantations on formerly cultivated land are most frequently infested; reproduction in well-established infestations, and red pine mixed with jack pine are attacked occasionally *(658)*.

Hylobius warreni Wood, **Warren's collar weevil**, attacks most species of conifers growing on moist to wet sites in southern Canada and south to North Carolina in the Eastern United States. The adult is a large, robust, reddish-brown to black weevil, from 12 to 15 mm long. The wing covers are thick, tough, and veinless, and each bears 10 rows of longitudinal punctures. The hindwings are vestigial. Eggs are deposited around the root collars of healthy trees, and the larvae feed in the inner bark and cambium of roots and root collars for 1 to 2 years. Infested trees bleed heavily at the ground line and severely injured ones may be completely girdled and killed. Up to 40 percent of the trees in a 40-year-old Scotch pine stand in Quebec is reported to have been killed by the species. The species has been described in detail *(1250)*.

Hylobius pinicola (Couper), **Couper's collar weevil**, occurs throughout the range of *H. warreni* and apparently breeds in the same species of trees. The adults of the two species are similar in appearance, but the hindwings of *H. pinicola* are fully developed.

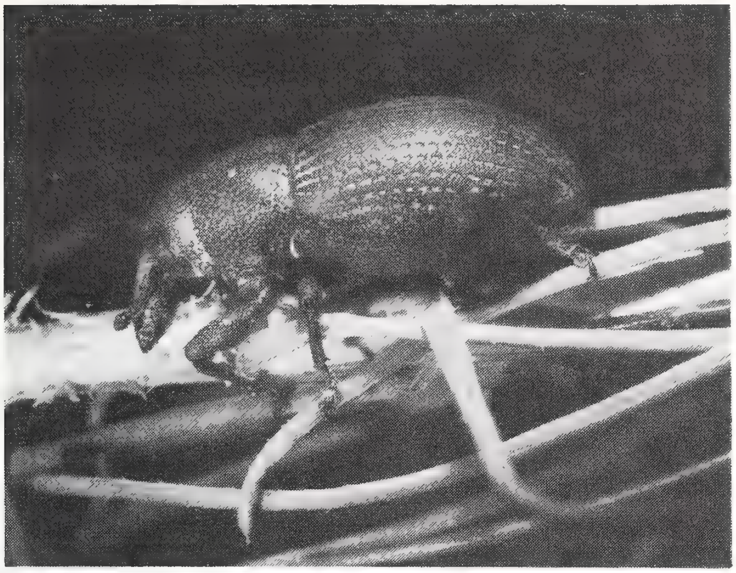
Hylobius congener Dalla Torre, Schenkling, & Marshall occurs from the northeastern coast to Alaska, and in the East breeds in the inner bark of logs and stumps of red, Scotch, and eastern white pines. It will also attack larch and spruce. Adults range from 5.8 to 9.0 mm in length. The body is brown to black, the thorax without scales, but the foretibia of the male has a fringe of white hair.

Adults emerge from hibernation in May and eggs are laid in logs and stumps. Logs seem to be preferred. Larvae become prepupae in chip cocoons in August and September and overwinter in the prepupal stage. The adult stage occurs in July and August. They then feed on slash and logs until hibernation *(822)*. Recently this species has been found to attack seedlings in plantations causing up to 40 percent mortality. Removal of litter from around seedlings has reduced damage *(606)*.

The **southern pine root weevil**, *H. aliradicis* Warner, was discovered attacking the roots of healthy young pines with root-collar diameters of 0.5 to 5 cm in southern Georgia *(361, 1247)*. The larvae hollow out the smaller roots and bore extensively in the root collar. Heavily infested trees are killed. The most serious infestations are in plantations up to 4 years old on disturbed sites.

The **pitcheating weevil**, *Pachylobius picivorus* (Germar), occurs throughout the Eastern United States, but is most common in the South. It attacks various species of pine, including shortleaf, loblolly, and slash pines. The adults feed on the inner bark of small twigs of residual pines and on stems of small pine seedlings (fig. 150). Larvae bore in roots of recently cut or killed pine trees. Damage is often serious in recently cut pine areas, especially where a new crop of seedlings is established during the first year after cutting the old stand. Adults are dark brown, robust, and

clothed with patches of short, flattened, yellowish or reddish-brown hairs. The tibiae are thick with the outer part enlarged; the tarsi are densely hairy underneath with the third segment bilobed.



F-532347
Figure 150.—Adult pitcheating weevil, *Pachylobius picivorus*.

Adults are attracted to and breed beneath the bark of dying pine stumps or roots. To lay eggs, the female bores directly down through the soil to green roots, sometimes to a depth of 1 m. Eggs are deposited in the cambial region of roots as small as 5 mm in diameter. Burrowing may occur as far as 8 m from the stump. Small piles of large soil particles surround the entrance holes into the soil. The newly hatched larvae feed beneath the bark, packing their mines with fine, red, boring dust and frass. The surface of the sapwood may be etched, depending upon the number and size of the larvae and the size of the root. Mature larvae excavate cells and construct chip cocoons in which to pupate.

When there are many larvae, these cells are formed in the wood. Adults emerge in 6 to 11 months, depending on the season in which the tree was cut. Then they fly to newly cut areas where they feed and repeat the cycle. Most adult feeding occurs at night on seedlings near fresh stumps, but some feeding also occurs on cloudy days *(444, 1193)*.

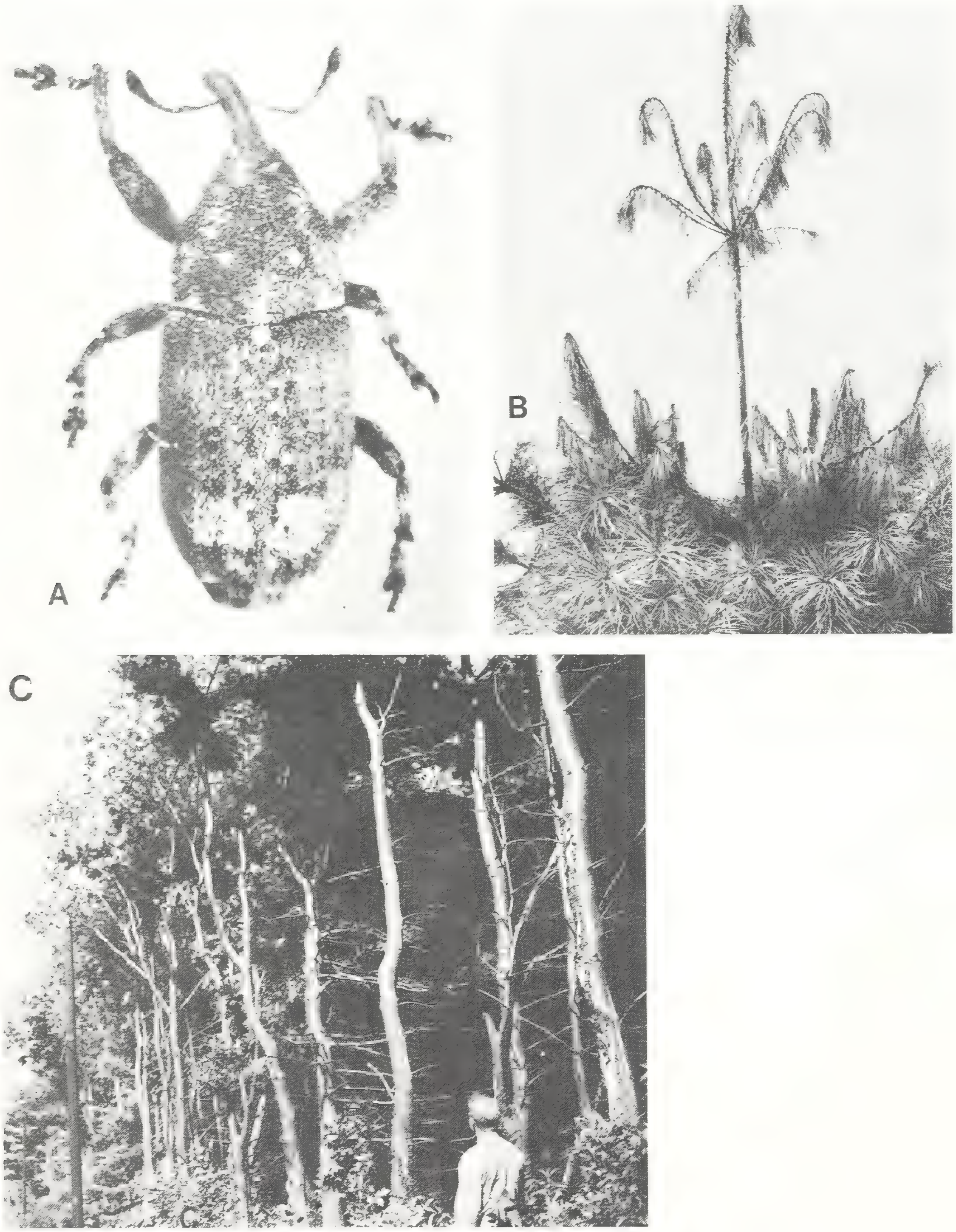
Damage varies with the season, and with the size and vigor of the tree. All of the buds, bark, and foliage may be removed to the ground. Roots as deep as 20 cm may be damaged. Attacks on newly established seedlings are usually severe. Mortality is particularly severe among seedlings planted within 3 months after overstory pines are cut. Heaviest attack with resulting seedling mortality occurred in eastern Texas between March and June. Later, in July and August, very little feeding occurs and damage mainly consists of puncture wounds and the removal of patches of bark. Feeding in autumn is very limited.

Pine seedlings may be planted safely during the winter in eastern Texas on areas cut earlier than the previous July. Farther north, a longer wait may be necessary. Seedlings should be chemically treated before planting on areas cut within 6 months. Stands may be cut during seed years without danger of excessive losses to regeneration *(934, 1193)*.

The bark weevils of the genus *Pissodes* attack both living and dead conifers. There are about 30 species in North America; their taxonomy is not altogether clear.

The **white pine weevil**, *P. strobi* (Peck), is able to feed and breed in a large number of spruce and pine species, both native and exotic. As a consequence, its range extends from coast to coast *(1120)*. In eastern North America, eastern white pine is the most common host, but Norway spruce, wherever it has been planted, is attacked with almost equal severity.

The adult (fig. 151A) is a small brown weevil 4 to 6 mm long. The elytra and body are covered with irregularly shaped patches of brown and white scales. Near the apex of each elytron there is a large white patch and a brown patch. In *P. strobi* these two patches are close together, and brown and white scales are often found intermixed.



F-482574, 482573, 482572

Figure 151.—White pine weevil, *Pissodes strobi*: A, adult; B, infested terminal of a young eastern white pine; C, eastern white pines deformed by white pine weevil attack.

The adult weevils spend the winter in the litter. They emerge from hibernation during March, April, and May in response to temperature, and feed on the cambial tissue of the main stems of the host. Most of the feeding is done within 25 cm of the terminal buds. The eggs are laid in some of the cavities made in the bark by the females when they feed. Eggs hatch in 7 to 10 days and the young larvae bore downward in the cambium under the bark. When there are many larvae they feed side by side in a ring around the stem. Toward the end of July the larvae begin to make chambers in the woody part of the stem. The shreds of wood removed are placed on top of the chamber to form a chip cocoon. The larvae pupate in the chambers and 10 to 15 days later emerge as adults. The adults disperse over all parts of the tree and feed until late fall; this differs from their spring-feeding habit. Sometimes, this feeding alone is severe enough to kill entire shoots.

The white pine weevil is the most serious insect pest of eastern white pine in North America. Its damage results in two types of loss: (1) reduction in volume, and (2) lumber degrade in the remaining volume. Studies in New Hampshire showed an estimated volume loss of 40 percent in the saw-log portion of sawtimber trees and 70 percent loss in the portion above saw-log limits of merchantability. The average loss in pole-size trees was 13 percent *(1254)*.

The first evidence of attack in the spring is pitch flow from feeding punctures on the terminal shoots *(534)*. Later, the new growth appears stunted, and finally, the needles wilt (fig. 151B). Trees up to 1 m tall may be killed. Killed terminals on taller trees are replaced by one or more branches of the topmost living whorl assuming vertical growth. This results in crooked or forked stems (fig. 151C). Trees suffering this type of damage for several years become multiple-stemmed, cabbage-shaped, and worthless.

The white pine weevil has been studied intensively, and much has been learned about its biology, ecology, and control. As a result of these investigations, the following management practices have been recommended for reducing losses to white pines: (1) planting white pines with hardwoods or under a hardwood cover; (2) planting white pine on medium soils only, where soil matting or hardpan does not occur within 1 m of the surface and where the trees will not suffer from competition with hardwoods, or jack or red pines; (3) selecting and pruning the least injured pines for an improved final crop in heavily infested stands; and (4) removing less desirable trees from white pine stands *(236, 309, 762, 823, 1362)*. Other types of indirect control, such as that exerted by insect parasites, predators, and birds, are helpful in preventing excessively high weevil populations but are incapable of preventing intolerable levels of loss *(525, 1191)*. Key factor analysis suggests that larval, pupal, and winter submortalities are the major influences on population change *(308)*. Drench-spray of terminals at the time adults emerge from hibernation provides protection *(516)*.

The **northern pine weevil**, *P. approximatus* Hopkins, a close relative of the white pine weevil, occurs from the Atlantic Coast to Manitoba in Canada and southward to Minnesota and North Carolina in the United States. Its preferred hosts appear to be red and Scotch pines, but it also attacks eastern white, pitch, jack, shortleaf, Virginia, Table Mountain, and Austrian pines, and red, black, and white spruces.

The adult is similar to the white pine weevil. It is larger, and the snout is proportionately longer. The distal brown and white spots on the elytra rarely overlap in *P. approximatus*. This is the single most reliable morphological feature by which these two species can be distinguished from one another *(414)*. The taxonomic

position of *P. approximatus* and *P. nemorensis* (Germar), discussed later, remains unclear. With the use of multiple discriminant analysis, these two species and *P. strobi* can be separated on the basis of external morphology *(490)*.

Winter may be spent in the larval, pupal, or adult stage, but most overwinter as adults in the duff and topsoil beneath infested trees. Occasionally, they may be found under scales or in the crevices of the bark of these trees. In the spring the weevils leave their hibernation sites and feed for several weeks on the inner bark of pine branches and on the stems of seedlings and small trees. Individuals that overwinter as larvae and pupae complete their development and emerge as adults in July and August.

The insect breeds beneath the surface of the bark on recently cut stumps and logs, and on the main stems or branches of dead or dying trees. Attacks occur on the tree from the roots up to branches as small as 1 cm in diameter. Attacks also occur at the root collar and on the lower stems of apparently healthy young trees. Eggs are deposited in pockets chewed through the bark by the female.

A pocket usually contains only one egg, but as many as five can be found. A larva may feed in any direction from the site of the egg, but usually follows the grain of the wood. Larvae pupate in chip cocoons usually on the surface of the wood but the chamber can be 1 to 2 cm below the surface.

Damage is often severe in regions where there are large quantities of breeding material, such as fresh stumps in Christmas tree plantations and in stands under intensive management. Because of the scarcity of breeding material in natural pine stands, damage there is of little consequence. Damage in nurseries and plantations can be reduced by destroying breeding sites or rendering them unsuitable for egg laying *(420)*.

The **deodar weevil**, *P. nemorensis* Germar, occurs in the Southern States north to Pennsylvania, and breeds in the true cedars, deodar cedar, Atlas cedar, cedar of Lebanon, and some pines, notably loblolly, shortleaf, and longleaf. The adult (fig. 152) is similar to *P. approximatus* and can be distinguished by discriminant analysis *(490)*. Damage is of three principal kinds—feeding on young shoots of the crown in sapling and pole-size trees, terminal killing by both adults and larvae, and branch-end flagging on pole-size and small saw-log-size trees. Attacks have been made directly on boles of trees 6 to 12 m tall, which killed the trees *(948, 952)*.

Courtesy Duke Univ. Sch. For.

Figure 152.—Adult of the deodar weevil, *Pissodes nemorensis*.

The adults are active all winter and lay eggs during this time. Eggs are deposited in the inner bark through holes chewed in the bark. The larvae feed beneath the bark in a manner somewhat similar to that of white pine weevil larvae, girdling and often killing the stem. Evidence of their presence is the swelling of the bark over feeding areas. Pupation occurs in chip cocoons in the wood. Adults apparently aestivate during the summer months. They again appear in the fall to feed on the twigs and leading shoots. Apparently, depending on location, all stages can be found throughout the year. May is the month of greatest adult emergence.

Several other species of *Pissodes* also attack various coniferous species in eastern forests. *P. affinis* Randall breeds in the stumps and logs of eastern white, red, jack, and Scotch pines from New England to the Lake States. The adults feed on the inner bark of branches of living trees up to 17 m tall. They are dark brown or black, from 5 to 8 mm long, and are marked with white spots. *P. dubius* Randall, **balsam bark weevil**, breeds in windthrown, dying, or recently dead balsam fir and red spruce. It is probably the most important insect attacking dead and dying balsam fir following spruce budworm defoliation *(1182)*. It also commonly attacks balsam fir weakened or killed by the balsam woolly adelgid. *P. rotundatus* LeConte, **small spruce weevil**, and *P. fiskei* Hopkins breed in windthrown red spruce.

The **New York weevil**, *Ithycerus noveboracensis* (Forster), is the only species of the subfamily Ithycerinae known in the East. It is sometimes placed in a separate family, Belidae. The adult is one of our largest weevils, 12 to 18 mm long. The body and elytra are covered with prostrate ash-gray and pale-brown hairs that give the insect a mottled appearance. It is widely distributed in the Eastern and Central States, but is most abundant in the Mississippi River Valley *(304)*. Adults have been collected from oak, hickory, beech, and a number of fruit trees. The larvae are thought to breed in twigs and under branches of oak *(1027)*.

The **pine gall weevil**, *Podapion gallicola* Riley, occurs throughout the Eastern United States and southeastern Canada. It breeds in red, pitch, and Virginia pines. The adult is black and about 5 mm long. During June, eggs are laid in niches chewed into the bark of 1-year-old twigs. Young larvae feed first on the sides and floor of the egg niche and then bore into the cambium. Here they separate and tunnel outward from the niche. They continue to feed through three seasons. Pupation occurs in funnel-shaped cells in the bark during May of the fourth season. Galls are formed by hypertrophy of the xylem tissue surrounding each larva. The galls first appear as slight swellings on one side of the stem *(1333)*. By the time the adults emerge, these swellings are larger, generally ovoid, and taper gradually toward the distal end (fig. 153). Old galls continue to enlarge, even after the insects leave them, some reaching a length of 37 mm. When several galls are formed on a small branch, the branch may be killed *(1323)*.

The members of the genus *Magdalis* are small cylindrical weevils frequently with toothlike spines at the anterior corners of the pronotum.

The **black elm bark weevil**, *M. barbita* (Say), breeds in the trunks and branches of unhealthy elms from North Carolina to southern Canada. Adults are jet black, have long slender beaks, and are about 6 mm long. They emerge in May or June and deposit their eggs in the bark. The larvae feed in the inner bark and sapwood, constructing galleries up to 4 cm long. Pupation occurs in oval cells just beneath the bark. There appears to be one generation per year. The bark of heavily infested trees may be literally peppered with small, circular, emergence holes.

The **red elm bark weevil**, *M. armicollis* (Say), occurs in the Eastern States and southern Canada and breeds in dying or recently dead elms or occasionally in dead

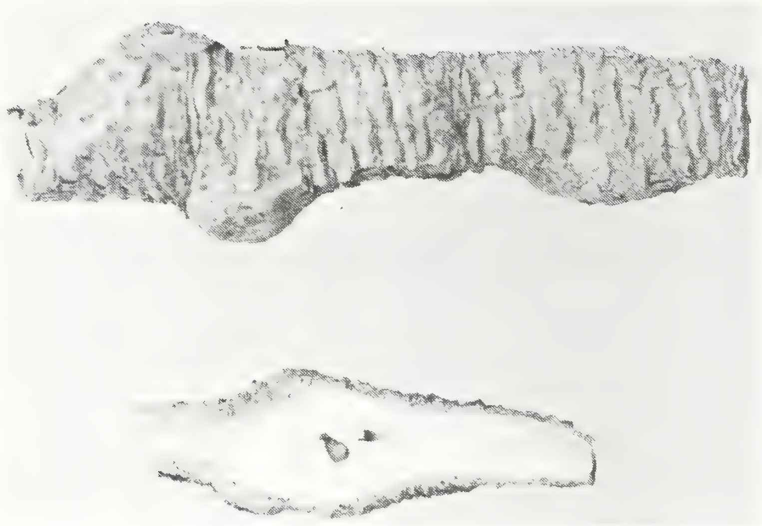


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Figure 153.—Galls in pine produced by the pine gall weevil, *Podapion gallicola*.

branches of living, suppressed elms. The adult (fig. 154) is reddish and somewhat smaller than the adult of the black elm bark beetle. Eggs are deposited in punctures in the bark, often in groups around knots or at the bases of twigs. Larval tunnels usually radiate away from the egg-laying site and follow the grain of the wood, scarring both the inner bark and the wood. Pupation occurs in cells at the end of the tunnels. There is one generation per year *(584)*.

Magdalis perforatus Horn breeds in the dead and dying branches of pines from Canada to Florida. The adult is bluish black, wedge shaped, shiny, and from 4 to 6 mm long. Eggs are deposited singly in pits chewed in the base of needle fascicles at or near the tips of branches. The larvae bore to the center of the stem and then tunnel through the pith toward its base. Trees under 4 m tall killed by insects or disease appear to be preferred; however, slash left during thinning or pruning operations and the dead, lower branches of old trees in closed stands are also attacked. Adults feed on the new shoots of pines, usually on trees growing in young, open stands. Prepupae overwinter in the pith. Pupation occurs in May, and adults emerge in June *(822)*.

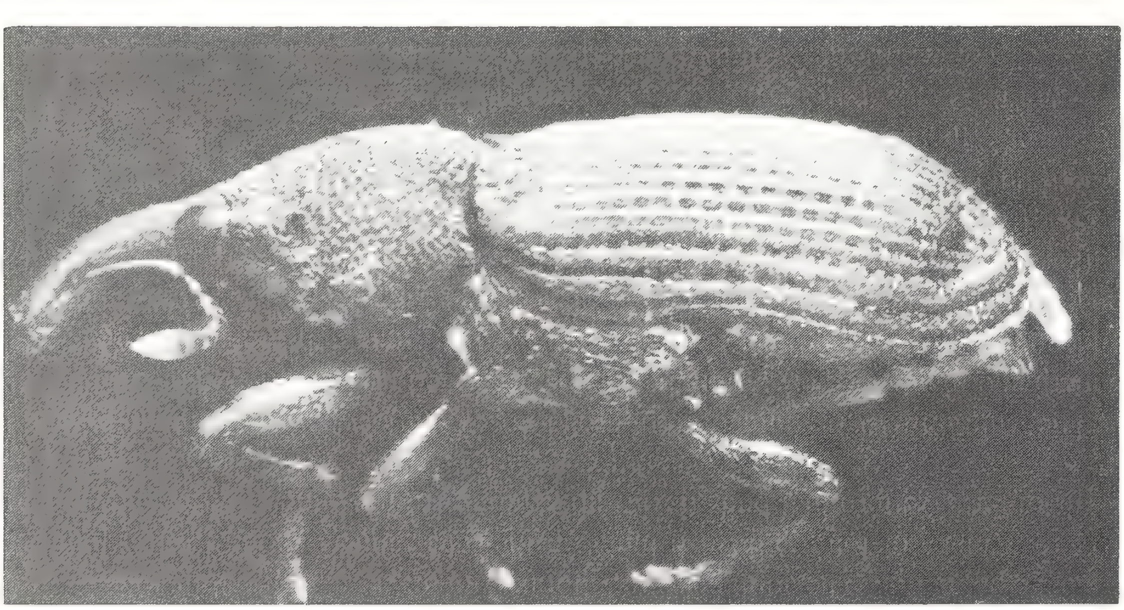

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Figure 154.—Adult of the red elm bark weevil, *Magdalis armicollis*.

Several other species of *Magdalis* are also encountered in eastern forests: *M. austera* Fall and *M. hispoides* LeConte are found on the needles of eastern white pine in the Northeast *(987)*. The adults bore through the scales of succulent, young needles, causing the distal portions of the injured needles to turn yellow and break off. *M. austera substriga* Fall is found on young Scotch pines; *M. olyra* (Herbst), on weakened hickories; *M. salicis* Horn, on willow and chestnut; and *M. barbicornis* (Latreille) and *M. pandura* (Say), on elms.

The genus *Curculio* is represented in eastern North America by 15 species *(478)*. These attack the seeds of nut-bearing trees. Most attack acorn, but several species are important pests on hickory, chestnut, and pecan. Injury is caused by the larvae eating the contents of the nuts *(150)*. Damage can be severe; the entire seed crop of some tree species is destroyed in some years. *C. caryae* is considered the major insect problem in commercial pecan culture *(183)*.

The life history of curculios is essentially the same for all species. From 2 to 3 weeks before the nuts ripen, the adults appear. The female lays her eggs in chambers chewed in the nut near the inner surface of the shell. Usually one egg is laid in each chamber. After hatching, the larvae feed for several weeks. When mature, they leave the nut to form pupal cells underground. However, pupation is usually delayed 1 or 2 years and sometimes as long as 5 years. The pupal stage lasts up to 3 weeks and maturation of callow adults may take another 20 days.

In the adult stage, species of the genus can be differentiated by snout shape and length, characteristics of the mesosternal intercoxal process, antennal insertion, leg structure, and hair and scale pattern *(478)*.

The **pecan weevil**, *C. caryae* (Horn), breeds exclusively in the nuts of the genus *Carya*. Except for the more northerly and eastern portion, this weevil is found throughout the range of hickories. Adults are dark reddish-brown and densely covered with golden to dark-brown hairs and scales. The body length varies from 7.5 to 12 mm. The female snout is longer than the body and down-curved in the apical quarter of its length. The male snout also curves down but is rarely longer than one-half the body length. Adults emerge in July and August. Eggs are laid in maturing nuts and the larvae leave the nuts in September and October, sometimes when the nuts still cling to the tree. Most larvae spend two winters in the pupal cell before pupation. *C. caryae* is a serious problem in commercial pecan orchards. Early maturing cultivars offer some promise of reducing damage; however, weevil emergence, dependent on rainfall, is erratic, so in some years the crop is heavily infested *(184)*. Most orchardists depend on insecticidal control. A number of compounds are registered for use *(966)*.

The **large chestnut weevil**, *C. caryatrypes* (Boheman) (the largest *Curculio* in the East), and the **small chestnut weevil**, *C. sayi* (Gyllenhall), breed exclusively in chestnut. At one time they were common, but since the passing of the American chestnut they have become rare. They have been reduced to remnant populations in orchards and isolated trees of introduced chestnut species, but they can be a serious problem that requires insecticidal control in these instances *(968)*.

The **hazelnut weevil**, *C. neocorylus* Gibson, breeds exclusively in hazel species. It is a dark reddish-black weevil with somewhat lighter legs and antennae. The body is covered with yellow to gray scales and hair that may have bands of darker scales on prothorax and elytra. They are 6.0 to 7.5 mm long.

All other species of *Curculio* found in the East feed on oak. Some, like *C. fulvus* Chittenden, utilize only one species, live oak; others such as *C. nasicus* (Say) and *C. iowensis* (Casey), use three or four species. At the other extreme are species like

C. sulcatulus (Casey), which feeds on almost all oak species but prefers the red oak group, and *C. proboscideus* F., reported from more than 20 species of oak *(1230)*.

The **willow flea weevil**, *Rhynchaenus rufipes* (LeConte), occurs in eastern Canada and south and west through the Eastern States to New Mexico. Willow is its preferred host, but it also feeds on many other hardwoods such as elm, red maple, aspen, red oak, gray and paper birches, cherry, serviceberry, and apple. The adult is black, broadly elliptical, and about 2 mm long. The eyes are large and almost meet in front, the antennae are reddish yellow and elbowed, the scutellum is white, the legs are reddish yellow, the hind femora are thick and fitted for jumping, and there is a small white spot at the base of the wing covers.

In Maine, winter is spent in the adult stage beneath loose bark, under stone walls, in debris, or in the soil. Overwintering adults emerge in early spring, fly to their hosts, and feed by eating circular holes in opening buds and new leaves. Eggs are laid in pits on the underside of leaves, and the larvae feed almost entirely within the tissues of the leaf, forming large blotch mines. Pupation occurs within the mine and new adults appear in August. In heavily infested areas, they may crawl over buildings in such large numbers as to be a nuisance *(905)*.

The **apple flea weevil**, *R. pallicornis* (Say), feeds on apple, hawthorn, winged elm, hazelnut, and quince from New York to Illinois and Missouri. Adults are black and about 2.5 mm long.

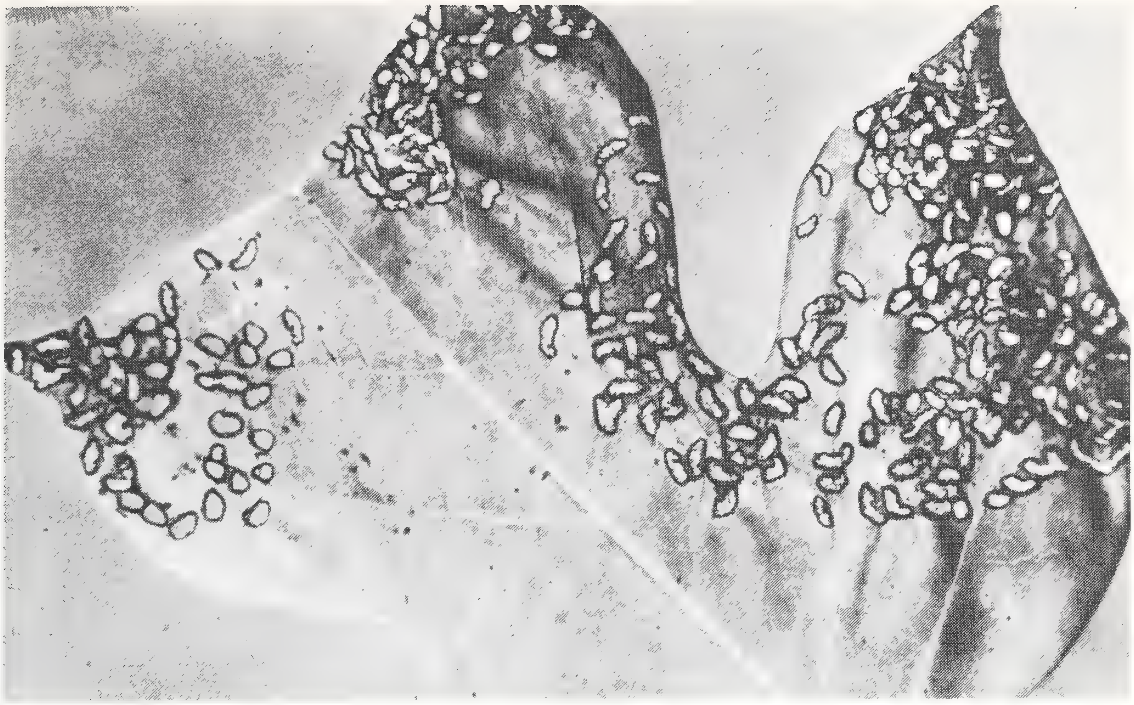
Odontopus calceatus (Say) has been reported from most Eastern States wherever its host plants—yellow-poplar, magnolia, and sassafrass—are found. Adult weevils are 2.5 to 3.9 mm long, and from 1.4 to 2.4 mm wide. Most are black with dark-brown antennae, mouth parts, and tarsi. Southern specimens may have yellow tarsi and antennal segments.

In the Gulf States, adults emerge in early February, but not until late April or early May in the northern reaches of its range. At first they feed on buds and stipules. Later, they feed on expanding leaves producing typical oval or rice-shaped holes (fig. 155). The females lay their eggs in the leaf midrib on the underside of leaves. Upon hatching, the larvae feed in the leaf blade; as many as 19 larvae have been reported in a single mine. When feeding is done, the larvae weave spherical cocoons in the mine and pupate. New adults emerge during the summer months. After a brief period of feeding, mostly on the under surface of leaves, the adults enter aestivation. Then, apparently with no further activity, they hibernate in the leaf litter. Late spring frosts can cause high mortality in the northern parts of the weevil's range *(177)*.

This species has been particularly abundant on yellow-poplar in eastern Kentucky since 1960. Heavy infestations have also occurred in Ohio, West Virginia, Virginia, and Tennessee. Prior to 1960, it seems to have occurred most commonly on sassafras and magnolia. Parasites have destroyed up to 50 percent of the pupae in certain areas of Kentucky.

The **poplar-and-willow borer**, *Cryptorhynchus lapathi* (L.), is a native of Europe and Asia. It was first reported in North America in New York in 1882. Since then it has spread across the continent in southern Canada. In the East, it is found as far south as South Carolina. Willow is its primary host, but poplar, except quaking aspen, is attacked and species of birch and alder are occasionally infested. Infestations in plantations and ornamentals may require insecticidal control to prevent serious damage.

The adult is 8 to 10 mm long (fig. 156). The snout is as long as the head and thorax combined, and the elytra, at the base, are a third wider than the thorax. The



F-519311

Figure 155.—Adult feeding damage to yellow-poplar leaf by *Odontopus calceatus*.

F-519950

Figure 156.—Adult of the poplar-and-willow borer, *Cryptorhynchus lapathi*.

antennae and tarsi are reddish brown, the body black. The body is covered with black and yellow or white scales intermixed with erect black bristles. The white scales predominate on the apical third of the elytra.

Adults appear in late July and August and feed on the inner bark of young shoots. Eggs are deposited singly or in groups of two to four in slits cut in corky bark, often in lenticels and scar tissue. Young larvae feed in the cambial region and outer layers of sapwood. They tunnel in all directions and push their borings out through small holes. In late fall, they hollow out small chambers in the inner bark, and there spend

the winter. Feeding is resumed in the spring. The larvae usually bore around the branch or stem. When ready to pupate, the larvae bore upward and construct cells in the center of the stem. There is one generation per year.

The first evidence of attack is the occurrence of dead patches or cracks in the bark on the trunks of small trees or on the branches of larger ones, and the presence of small holes chewed in the bark. The wood under these patches eventually becomes honeycombed with larval tunnels. Branches and small trees may be completely girdled, or so badly weakened by tunnels that they break. All poplars and willows over 2.5 cm in diameter are subject to attack, especially recently planted trees and nursery stock *(530, 1096)*.

The genus *Conotrachelus*, like the genus *Curculio*, contains a number of species important as pests of acorns, nuts, and fruit. The adults of *Conotrachelus* resemble those of *Curculio*, but tend to be smaller. They have shorter and less curved beaks, the body is scaled on the upper surface, and the prosternum is grooved for reception of the beak.

Probably the most economically important species is the **plum curculio**, *C. nenuphar* (Herbst). It breeds in plums, cherries, peaches, apples, and other fruits. This weevil is a serious pest in commercial orchards, where repeated applications of insecticides are required during the first growing season for control. A number of insecticides are registered for use. The **quince curculio**, *C. crataegi* Walsh, is also a pest in orchards. It attacks quince, pear, peach, and hawthorn fruits. Some races of this species that attack apple have been found *(813)*.

There are three acorn-infesting species in the United States. *C. naso* LeConte can be distinguished from the other two by the absence of femoral teeth; *C. carinifer* Casey has prothoracic punctures larger than elytral punctures; and *C. posticatus* Boheman has prothoracic punctures that are not larger than those on the elytra *(477)*.

Conotrachelus naso occurs from Maine to Florida and west to Minnesota in the Eastern United States. It has been bred from acorns of 16 species of oaks. The adult is shiny black to light reddish-brown. Light and dark scales make varied patterns on the elytra and thorax. White scales usually make four spots on the thorax and base of the elytra and a band on the distal third. Adults are from 4.8 to 6.6 mm long. The snout is moderately stout and curved, and longer than the prothorax. It is slightly longer and less stout in the female than in the male. Adults emerge from April to August, depending on locality. Eggs apparently are deposited in damaged, cracked, sprouted, or previously infested acorns. The larvae mature in 2 or 3 weeks. Then they vacate the nuts and enter the soil to pupate. New adults emerge about 1½ to 3 months later.

Conotrachelus carinifer occurs in the Coastal States from New Jersey to Texas and west to Arizona. It has been reared from the acorns of eight species of oaks. The wing covers are dark reddish-brown with a few black areas. These are covered with brown to white setae in patches and bands. The prothorax is black and clothed in pale-brown to white setae. The beak is curved and longer than the prothorax in both sexes. Adults emerge in late summer or early fall and begin laying eggs within 4 days. The larvae become mature and vacate the acorns within 12 to 18 days.

Conotrachelus posticatus occurs throughout much the same range as *C. naso*. It is known to breed in acorns from nine species of oaks. The adults have dark reddish-brown wings with black splotches, the black sometimes predominating. The elytra are sparsely covered with pale tan, yellow, and white setae with some patches. Usually there is a narrow, curved posterior band. Their bodies are 4 to 5 mm long.

The beak is feebly curved and longer than the prothorax. Adults emerge from June to August. The eggs, like those of *C. naso*, are deposited in damaged, cracked, sprouted, or previously infested acorns. The larval stage lasts 10 to 30 days. The first winter is spent as a larva in the soil; the second, as an adult beneath leaves on the ground *(476)*.

Other common eastern species of *Conotrachelus* include: *C. juglandis* LeConte, which breeds in the nuts, stems, and leaf petioles of a number of species of *Juglans*; *C. retentus* (Say), which attacks the nuts of black walnut and butternut; *C. affinis* Boheman and *C. hicoriae* Schoof, two closely related species that are difficult to separate and which breed in hickory nuts; *C. aratus* (Germar), which attacks young shoots and leaf petioles of hickory; *C. anaglyptius* (Say), which breeds in the tissues around fresh wounds on various deciduous trees including hickory, birch, maple, and oak; and *C. elegans* (Say), which breeds in *Phylloxera* galls on hickory leaves. Another weevil, *Anthonomus suturalis* LeConte, also develops in *Phylloxera* galls on hickory and pecan *(467)*.

The subfamilies Rhynchophorinae and Cossoninae are placed in the family Rhynchophoridae by some authors.

Rhynchophorus cruentatus (F.), the **palmetto billbug**, occurs from North Carolina to Florida and Louisiana and breeds in the trunks of weakened palm trees and cabbage palmettos. The adult has a red thorax with black margins, shiny black wing covers, fringes of long yellowish hairs on the legs, and is about 30 mm long. It feeds on bruised terminal buds or on sap exuding from wounded or recently felled trees.

The subfamily Cossoninae, the broad-nosed bark weevils, contains several genera and many species. A number of species breed in the sapwood of hardwoods and conifers killed by bark beetles; others, some of which are important pests, breed in the woodwork of buildings. The larvae of all species cut meandering galleries across the grain of the wood and pack them tightly with granular frass except for that portion immediately behind their bodies. Adults may be found in the wood, but they usually occur under the bark about a year after the tree is killed. The larvae of a number of species have been described *(24)*.

Several species in the genus *Cossonus* breed in the sapwood of bark-beetle killed trees. *C. corticola* Say, a shiny black species—under the bark of dying pines; *C. platalea* Say, a flat, shiny black species—under the bark of hardwoods; *C. impressus* Boheman, a dull black species—in the sapwood of both conifers and hardwood (reported from Florida); and *C. concinnus* Boheman—under the bark of hardwoods.

Species of Cossoninae that attack and damage wood in buildings deposit their eggs in crevices in the wood. Adults of certain species reattack the wood from which they emerge, thus intensifying the damage they already caused. The more important eastern species are as follows: *Hexarthrum ulkei* Horn—damages woodwork in old buildings, often reducing the wood to powder; *Tomolips quercicola* Boheman—damages seasoned coniferous wood such as pine flooring and pecky-cypress paneling; and *Pselactus spadix* (Herbst)— occasionally damages damp wood beneath buildings and saltwater pilings above the high watermark.

Dryophthorus americanus Bedel occurs very commonly in hickory killed by the hickory bark beetle. *Stenoscelis brevis* Boheman is common in dead, dying, and rotting hardwoods.

Family Scolytidae

The family Scolytidae comprises a large, diverse, and important group of beetles. A small segment of the family is actually responsible for its bad reputation;

a somewhat larger group occasionally causes losses in forest products, while most species have never been economically important.

Two subfamilies are recognized *(1354)*: the Hylesininae and the Scolytinae. The Hylesininae are generally rounded behind, have a series of teeth or granules on the anterior margin of each elytron, and have the head visible from the dorsal aspect. The Scolytinae usually have a declivity at the posterior end, have no armament on the anterior margin of the elytra, and have the head either partly or completely concealed from above by the pronotum. Another mode of dividing the family Scolytidae is by feeding habit. The scolytid beetles of concern in the forest feed on the inner bark (phloeophagy), seeds and cones (spermophagy), wood (xylophagy), or on mutualistic fungi that they culture in wood (xylomycetophagy or ambrosia habit). The taxonomic divisions of the family do not necessarily correspond with the feeding groupings because the various modes of feeding have repeatedly evolved independently. This discussion of Scolytidae lists the genera and species by feeding habit and by approximate phylogenetic order within the feeding groups. Identification of some of the more important genera and species can be made by using illustrations and the descriptions of beetles' morphology, gallery systems, and hosts. For the most part, taxonomic treatises on the Scolytidae of North America *(1356)* and Canada *(153)* should be consulted when a reliable identification of a species of little economic importance is necessary.

Scolytid adults are typically soft and yellowish when first formed but soon harden and turn reddish to dark brown or black. They are cylindrical beetles, from about 0.9 to 9.5 mm long. The larvae are white, curved, legless grubs with enlarged thoracic segments. The heads and mandibles are usually strongly sclerotized and dark red-brown. Larvae of the Scolytidae are very similar to those of the Curculionidae (weevils).

When scolytids attack, the adults construct entrance tunnels into the inner bark (phloem), pith, wood, or cone axil, depending on the species. The entrance tunnel empties into a nuptial chamber or is simply elongated into an egg gallery. In conifers, pitch and sap may exude from these holes and harden at the bark surface to form a pitch or resin tube. Ambrosia beetles and most bark beetles push boring dust out through the holes. Egg tunnels of bark beetles may be entirely in the phloem but more often engrave the wood. Egg tunnels of wood-feeding (xylophagus) species may be deeply cut into the wood surface or may be completely in the wood. Tunnels of ambrosia beetles are always in the sapwood and may be simple, branched, or compound. The females of most species deposit their eggs individually in niches cut into the sides of the tunnel and cover them with fragments of bark or wood. Others deposit groups of eggs in larger niches or grooves and cover them with boring dust. Still others, particularly some of the pith beetles and ambrosia beetles, place their eggs free in the tunnels.

When bark beetle larvae hatch they feed away from the egg tunnel, usually at right angles to it. Many species can be recognized by their host and gallery pattern. Ambrosia beetle larvae remain in the egg tunnel and feed on fungi growing on its walls. Most Scolytidae pupate in cells at the ends of larval galleries, in the wood, in the outer bark, or between the wood and bark. The adults remain in those cells until their exoskeletons harden, sometimes even longer. While there, they usually feed on whatever phloem or xylem remains after the larvae finish feeding. When ready to emerge, the beetles gnaw holes through the bark to escape. The majority of a particular colony will emerge within a few days. The ambrosia beetle adults emerge through their parents' entrance tunnels.

Most Scolytidae fly and attack a new host as soon as they mature and some species congregate under the bark of the new host to hibernate or mature sexually. A few species feed on the twigs, buds, or bark of other trees before attacking a tree for breeding purposes. Generally speaking, the adults spend only enough time outside the bark to find new host material. Exceptions are species *(Ips, Dendrocranulus, Trypodendron*, etc.) that overwinter in litter on the forest floor.

Beetles usually overwinter in the tree in the larval or adult stage, or in the forest litter as adults. In warm regions, eggs and pupae may also be present in winter. Activity is resumed with the advent of warm weather in the spring. Parent adults continue their egg laying in the extended portion of galleries started the year before or in newly constructed tunnels or freshly attacked trees. In the South, there usually are several generations per year. In the North and at high elevations, there may be only one or a partial generation per year.

Bark Beetles
Phloeophagus Scolytidae

In the United States, bark beetles kill an average of 25.5 million cubic meters of sawtimber and pulpwood annually. This accounts for 90 percent of all insect-caused tree mortality and 60 percent of the annual loss of timber to all causes *(1221)*. The most destructive eastern species, the southern pine beetle, inflicted an annual economic loss of $225 million by killing 9 million cords of pulpwood and 3 billion board feet of sawtimber from 1960 to 1978 *(969)*.

Most tree mortality is caused by species in the genera *Dendroctonus, Ips*, and *Scolytus*. Scolytids in other genera occasionally may kill or damage trees or indirectly cause their death by transporting pathogens from diseased trees where they breed to healthy trees in which they feed. Rapid death of mass-attacked trees is actually caused by fungi that the beetles carry in mycetangia (fungal pockets). The fungal inoculum is able to penetrate the resinous (or other chemical) resistance of the host; then the fungi colonize (and usually stain) the sapwood and disrupt the flow of water to the tree crown. Even the tree-killing bark beetle species may most often be restricted to breeding in broken or moribund material because healthy trees are able to resist attacks of beetles and fungi in the vital phloem-cambial region. However, bark beetles can overcome host resistance by mass attacks orchestrated by aggregation pheromones produced when the pioneer beetles attack a tree *(111)*. A sufficient population mass attack can kill any host, regardless of its vigor. When the attacking population is insufficient to exhaust the natural defense mechanisms of a tree, the host will survive and the attackers will be repelled or killed *(103)*. Success or failure of an attack can be visualized as a seesaw on which host resistance and beetle numbers are balanced on a fulcrum—time. The balance will be affected by an increase or decrease in either attack density or resistance, or a shift in the position of the fulcrum (duration of attack). This concept explains why bark beetle outbreaks generally follow a predisposing event (logging, flooding, drought, or fire) that reduces host resistance or allows for a dramatic increase in the bark beetle population. Once the population exceeds the threshold beyond which host resistance is a factor, tree killing will continue until the supply of hosts is exhausted or natural events (winterkill, disease, predation) reduce the population.

Major outbreaks of bark beetles have probably never been controlled by human intervention. However, timber losses in localized eruptions have been curtailed by direct action such as logging infested trees or felling them for treatment with insecticides, solar heat, or fire. Synthetic pheromones have been able to disrupt

local "spot" populations of southern pine beetles *(1026)*, and using pheromone lures for mass trapping European elm bark beetles has contributed to control of Dutch elm disease in urban areas *(716)*. Parasites and predators (especially woodpeckers) may keep endemic-level bark beetle populations from increasing, but probably do not cause the collapse of outbreaks. Foresters can assist in biological control of bark beetles by leaving a few dead and defective trees for nesting of woodpeckers rather than felling all cull material during thinning and logging operations.

A trap-log technique can be used beneficially against bark beetles that preferentially attack cut material. Trees are felled shortly before beetles are expected to fly. Infestation may occur naturally or be assured by baiting the trees with synthetic aggregation pheromone. Before beetle broods mature, logs are debarked, milled, etc. Although this method has been applied effectively against *Ips typographus* (L.) in Europe for three centuries *(1074)*, it has not been widely applied in North America. A modified trap technique in which trees are killed with cacodylic acid and baited with pheromone is more efficient because herbicide-induced drying of the bark inhibits brood development and renders follow-up action unnecessary *(943, 1233)*. The most satisfactory means of reducing losses to bark beetles is to prevent the occurrence of outbreaks by maintaining sanitation of logging debris, lightning-struck or windthrown trees, etc., and by promoting stand vigor by thinning and other cultural practices *(85)*. Loss in quality of softwood logs due to bark beetle-carried stain fungi can be avoided by prompt milling, ponding, or sprinkling of logs.

Subfamily Hylesininae

The genus *Hylurgops* is represented in eastern forests by only one species, *H. pinifex* (Fitch). This species is widely distributed in the Eastern United States and Canada where it breeds in logs, stumps, and basal portions of dead and dying pines, spruces, and larch. The adult is reddish brown to nearly black and from 4.5 to 5 mm long. The undersurface is black and the declivity is covered with small, ash-gray scales and a few long, erect hairs.

The genus *Hylastes* is represented by 15 species in North America, several of which occur commonly in the Eastern United States *(121)*. They usually breed in the bases or roots of dying pines and spruces or in stumps or the bottom sides of logs in contact with the ground. The adults occasionally kill pine transplants or young plantation trees by chewing the bases of the stems; otherwise, members of the genus are of minor economic importance.

Hylastes porculus Erichson occurs from Maine to the Carolinas and west to the Lake States. It breeds in stumps and roots of dying pines. The adult is dark reddish-brown to black and from 4 to 5.3 mm long. Adults are strongly attracted to freshly cut lumber or to ongoing construction. In the Southeast, they fly during the period April to November.

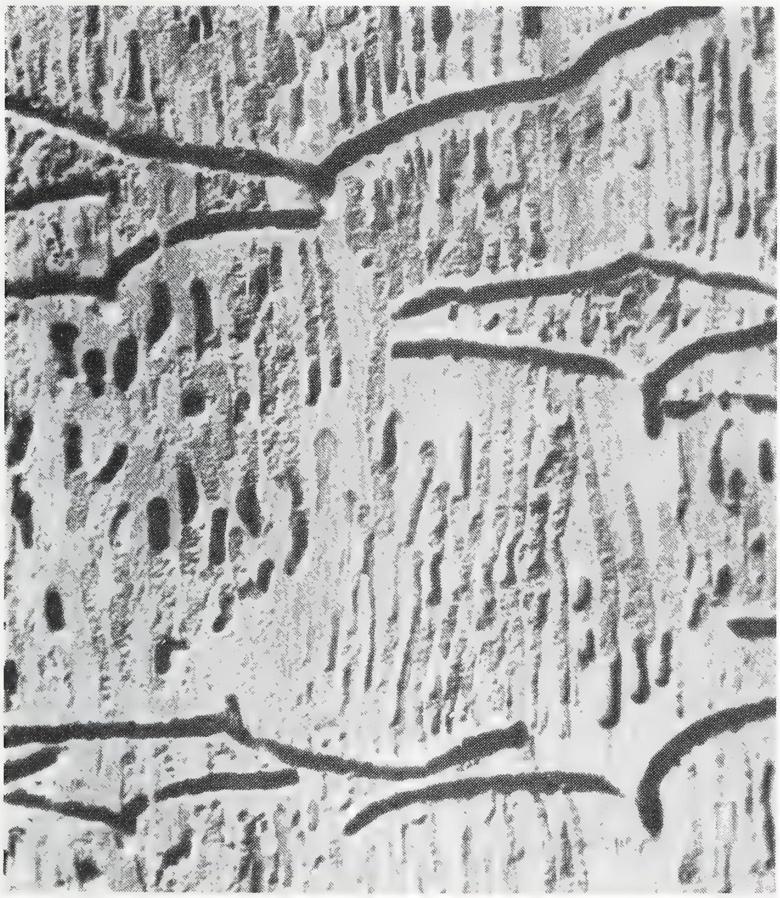
Hylastes salebrosus Eichhoff occurs commonly in the south Atlantic States. It has been recorded breeding in loblolly, longleaf, and shortleaf pines, and in spruces. It is also strongly attracted to freshly sawn lumber. The adult is dark reddish-brown and about 4.5 mm long.

Hylastes tenuis Eichhoff occurs over most of the United States. Its hosts include pines, spruce, and fir. The adult is dark reddish-brown to black and from 2 to 3.5 mm long.

Hylastes exilis Chapuis occurs in the Southern States from the District of Columbia to Florida and Texas where it infests various species of pine. The adult is dark reddish-brown and about 2.9 mm long.

The genus *Hylesinus* contains a number of species that breed by preference in various species of ash, and are commonly known as ash bark beetles. The adults differ from most other bark beetles in having variegated coloration produced by bands or spots of light-colored scales alternating with areas of dark scales. The body is rather stout, and the elytra gradually descend behind; the antenna has a seven-jointed funicle, with the club elongate, fusiform, and compressed. Favorite breeding material consists of recently cut or broken trees; however, living trees weakened by mechanical injury, disease, or fire may be attacked. Parasites and predators, especially the braconid, *Coeloides scolytivorus* (Cresson), and the clerid, *Enoclerus nigripes* (Say), provide a considerable degree of control at times.

Hylesinus aculeatus (Say), the **eastern ash bark beetle**, is the most common eastern species. It breeds in ash species throughout the eastern part of the United States and southeastern Canada. The adult is grayish brown with nearly black markings and is 2 to 3 mm long. Winter is spent in the adult stage in tunnels in the bark of living or felled trees. The adults emerge in the spring and fly to the trunks or limbs of recently felled, dying, or seriously weakened trees to breed. Egg galleries are constructed between the bark and wood, both of which are deeply engraved. The galleries are biramous and transverse, with the two arms connected by a short tunnel or nuptial chamber just below the entrance hole (fig. 157). Eggs are laid in niches along the sides of the gallery. The larvae feed away from the gallery, following the grain. Pupation occurs in deep oval cells between the bark and wood. There are one to three generations per year, depending on location. This species and the slightly larger *H. pruinosus* (Eichhoff) are economic pests to producers of rustic ash products; otherwise, these beetles cause little or no economic damage.

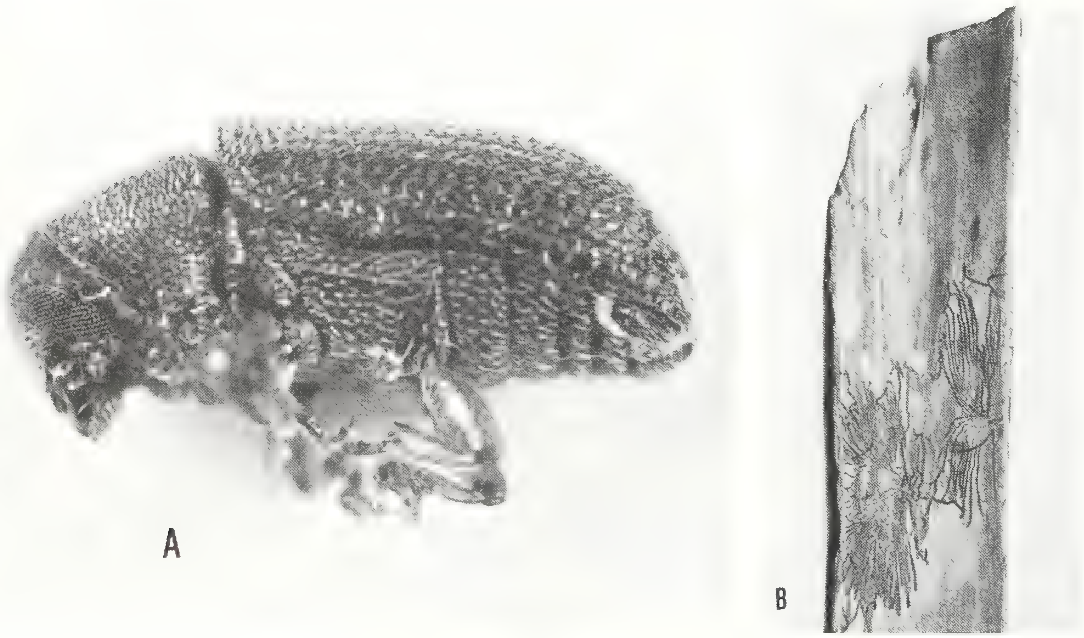


Courtesy Duke Univ. Sch. For.

Figure 157.—Transverse egg galleries and vertical larval tunnels of *Hylesinus aculeatus*, the eastern ash bark beetle, in white ash.

The genus *Hylurgopinus* is distinguished by its seven-segmented antennal funicle, the strongly chitinized first two sutures of the antennal club, and the widely separated forecoxae. One species occurs in North America.

The **native elm bark beetle**, *H. rufipes* (Eichhoff), breeds in various species of elm in southern Canada and throughout the Eastern United States north of Alabama and Mississippi. The adult is brownish black, thinly clothed with short, stiff, yellow hairs, and from 2 to 3.5 mm long (fig. 158A). The head is convex, thickly punctured, and nearly invisible from above; the antennal club is almost twice as long as wide; the pronotum is narrow in the front, densely punctured, and reddish at the rear; the elytral striae are composed of deep punctures; and the legs and abdominal sternites are red.



A, F-532844
B, courtesy G. N. Lanier, SUNY Coll. Environ. Sci. & For. photo by E. M. Gallagher

Figure 158.—The native elm bark beetle, *Hylurgopinus rufipes*: A, adult; B, gallery pattern.

Beetles overwinter as larvae or adults. Adults that mature during the late summer or fall fly to healthy elms in which they bore overwintering tunnels in the bark at the root collar or lower bole. In April and May overwintering adults emerge from hibernation chambers, crawl up the tree and burrow into the bark of small (1 to 5 cm in diameter) branches *(1201)*. Later they fly to dead and dying trees, broken limbs, or recently cut logs or limbs to breed. Usually, dying or fairly moist recently dead limbs at least 5 cm in diameter are selected. Entrance holes are made in bark crevices or under overhanging bark flakes and they penetrate directly to the surface of the wood. A biramous egg gallery is constructed with the arms extending away from the entrance hole at various angles (fig. 158B). The gallery may be constructed horizontally, but is most often inclined from the horizontal. Galleries may be constructed entirely in the bark, or they may scar the wood slightly. Eggs are laid on both sides of the gallery, sometimes very close together. Young larvae feed away from the gallery, usually following the grain. Pupation occurs in cells at the end of the larval tunnels in the bark. There appears to be two generations per year in the southern portions of the insect's range and one and one-half in the northern portions *(651, 1201)*.

Adults emerging from elms dying from Dutch elm disease often carry spores of the disease-causing fungus on their bodies. When they bore into the bark of healthy elms to feed or hibernate, some of the spores rub off onto the walls of their tunnels, inoculating the tree with the disease. In most of the United States, the native elm bark beetle has been displaced by the more aggressive smaller European elm bark beetle. In northern New York, New England, and Canada, where the latter species is limited by low winter temperatures, the native elm bark beetle is the primary vector of Dutch elm disease.

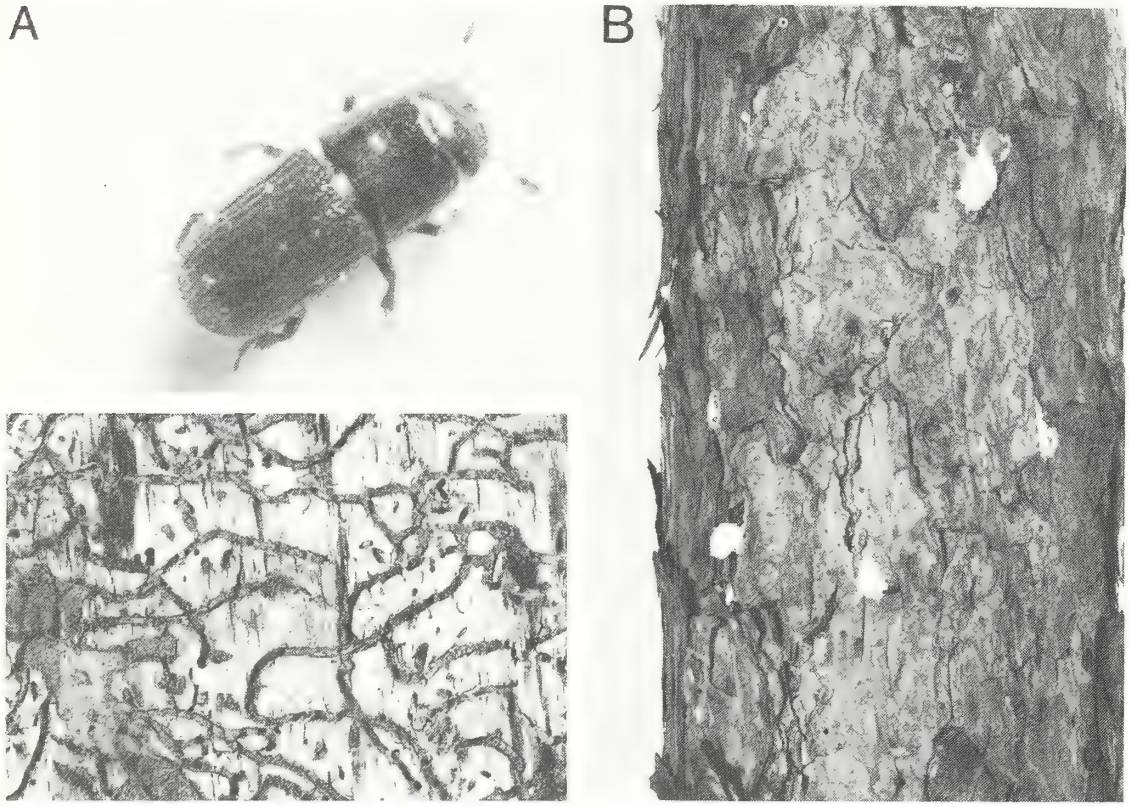
The genus *Dendroctonus* contains some of the most destructive insects affecting conifers in North America. The adults are reddish brown to black and from 2 to 9 mm in length. The body is cylindrical and rather stout; the head is broadly rounded and visible from above; the antennal funicle is five-segmented; and the short antennal club is sutured toward the tip. Important papers on the biology and taxonomy of the genus are available *(591, 1353)*.

The **southern pine beetle**, *D. frontalis* (Zimmermann), the most destructive of the eastern species of bark beetles, occurs throughout the Southeastern and Southern States. From 1948 to 1975 more than 14 million cubic meters of pine timber were killed during a series of outbreaks in the Southern States (fig. 159). The insect also occurs in Mexico, Guatemala, and Honduras. During a catastrophic outbreak in Honduras in the early 1960's, more than 55 million cubic meters of pine were killed. It breeds in all species of yellow pines in its range; also in eastern white, red, and spruce pines, and red and Norway spruce. Shortleaf, loblolly, Virginia, and pitch pines are the most highly favored among the yellow pines. Infestations in slash, longleaf, and eastern white pines are usually unsuccessful because of heavy resin exudations. Attacks on red spruce are also unsuccessful, the beetles dying in them after constructing short tunnels *(692)*.

F-531256

Figure 159.—Deteriorated loblolly pines 5 years after they were killed by the southern pine beetle, *Dendroctonus frontalis*.

The southern pine beetle adult (fig. 160A) is reddish brown to black and from 2.2 to 4.2 mm long. The front of the head has a distinct longitudinal median groove bordered by a narrow elevation of tubercles on each side; the pronotum is slightly narrowed at front, broadest at the middle, and about as long as wide; the elytra are as wide as and over twice as long as the pronotum; and the declivity is convex. The full-grown larva is a whitish, legless grub with a glossy reddish-brown head, and it is about 5 mm long.



F-531257

Figure 160.—The southern pine beetle, *Dendroctonus frontalis*: A, adult; B, pitch tubes on shortleaf pine; C, winding egg galleries.

Winter is spent in the bark in all stages—egg, larval, pupal, and adult. Emergence in the spring varies with the overwintering stage, geographic location, and climatic conditions. In the southern Appalachians, the overwintering adults emerge about mid-April, while those that develop from overwintering eggs may not appear until late June. The bark of trees through which the adults have emerged is peppered with small, round holes. Hibernating beetles do not attack healthy, living trees after they emerge. Instead, they seek out and invade trees attacked but not killed the previous fall *(590)*. Generally, beetles attack the middle and upper trunk first, especially in the Middle Atlantic States. Later they continue their attacks down the trunk to within 1.5 m or less of the ground. In the Deep South, overwintering adults emerge during warm periods in the winter and may attack the upper and lower portions of the tree from which they emerged. However, most of these beetles emerge in late February or early March and first attack the mid to lower trunk of new host trees. Continuing attacks extend the zone of attack down to the ground line and up into the base of the live crown.

The female bores directly into the cambium and constructs a nuptial chamber. Points of attack are characterized by the presence of distinct pitch tubes and fine reddish boring dust or white resinous boring particles in the bark crevices or on

upper leaf surfaces of understory vegetation (fig. 160B). The female is joined in the chamber by a male and after mating she begins construction of a gallery diagonally across the grain of the wood, etching the surface of the wood faintly. The direction of the gallery eventually is reversed, thus creating a typical S-shaped or serpentine pattern (fig. 160C). Eggs are deposited at intervals of 3 to 25 mm or more in niches in each side of the gallery, one egg per niche. Hatching occurs in 3 to 9 days, and the larvae tunnel away at right angles to the gallery. Young larvae initally produce threadlike mines which are visible when the inner bark is exposed. As the larvae continue to develop, they mine outward into the corky bark where they construct individual cells in which to pupate. Each adult bores its own emergence hole. All the adults in a given brood may emerge during a period of 10 to 32 days. Three to five generations develop each year in western North Carolina. In Virginia and West Virginia, four generations and a partial fifth occur; in the Deep South there are as many as seven per year.

Newly emerged beetles may attack adjacent trees or they may fly to stands some distance away. Trees under 15 years of age and less than 5 cm in diameter are rarely attacked. When outbreaks develop, scattered groups of pines growing under dense stand conditions, disturbed by recent logging or lightning damage, or on sites subjected to moisture stress and disease are attacked. Once an epidemic is underway, stands of all age classes and densities are vulnerable. Spot infestations, which may range from a few trees to stands occupying hundreds of hectares, are characterized by a central zone of defoliated trees, one or more adjacent areas of red-topped trees, and one or more peripheral fingers of infested trees with yellowish or green foliage extending out into the surrounding forest. The needles of pines infested during midsummer turn yellow in 2 or 3 weeks and reddish brown in 4 to 6 weeks. Death results either from the girdling of the main stem by the beetle or from the effects of the blue stain fungus, *Ceratocystis minor* (Hedgc.) Hunt, which the beetles introduce into the tree.

Southern pine beetle outbreaks appear to be caused by conditions that reduce tree or stand vigor, whether by natural phenomena or human intervention. Drought or flooding, overstocking, stand disturbance and site depletion are most often associated with initial infestations. Beetle populations increase rapidly in response to favorable host and environmental conditions and cause extensive damage. Only in the more northerly or high elevation areas of the insect's range do low winter temperatures serve as a check in terminating outbreaks *(73)*. A return to more favorable growing conditions tends to be associated with reduced beetle activity over large areas.

Management practices designed to improve and maintain the vigor of stands (e.g., timely thinning), and the removal of high-risk trees, such as those injured by recent logging, struck by lightning, or attacked and weakened by other insects, are helpful in reducing losses. Once an outbreak is underway, the salvage or chemical treatment of infested trees may be helpful in suppressing populations. To be most effective, these practices must be applied on a timely basis with first priority given to larger spots that have a greater volume of actively infested trees.

Several reviews of the life history and habits, natural enemies and associated organisms, sampling and population dynamics, impacts, utilization, site, stand, and climatic factors affecting stand susceptibility and vulnerability, silvicultural and direct control methods and materials have been issued *(86, 87, 107, 246, 247, 253, 310, 491, 535, 546, 706, 1155, 1180, 1195)*.

The **black turpentine beetle**, *D. terebrans* (Olivier), occurs from coastal Massachusetts, New York, and New Hampshire to Florida, Missouri, and Texas. The northern part of its range is coincident with stands of pitch pine near the Atlantic Coast. All species of southern pines and red spruce are attacked, but loblolly and slash pines apparently are the most frequently injured. The adult (fig. 161) is dark reddish-brown to black, and from 5 to 10 mm long. The head is densely granulate, roughly punctate, and convex in front. The pronotum and elytra are coarsely and shallowly punctate. Full-grown larvae are creamy white, legless, about 12 mm long, and have glossy reddish-brown heads.

Winter is spent in the adult stage in the northern parts of the insect's range. In the Deep South all life stages are present throughout the year. Eggs are principally laid in the basal 90 cm of the trunk and large roots of weakened and dying trees and stumps of recently cut trees. Green logs may also be attacked occasionally. The female bores a hole through the bark to the cambium. Here she is joined by a male and, working together, they excavate an egg gallery up to 25 cm wide and 50 cm long on the face of the sapwood, usually in a downward direction. Eggs are deposited in a long group on one side of the gallery. The larvae feed away from the gallery in the phloem. They feed together in groups and excavate large cavelike galleries, usually somewhat fan-shaped, and occasionally up to 30 cm across. When fully grown they construct pupal cells either in the corky bark or between the bark and wood. The adults emerge through holes chewed through the bark and fly to trees or stumps to start a new generation. Several may emerge through a single hole. There are two to three generations per year in the Deep South.

Beetles are attracted by terpenes released by stumps and injured trees. Trees weakened by fire, logging, adverse climatic conditions, or naval stores operations are also highly prone to attack. Occasionally uninjured, apparently healthy trees are infested. Attacks are usually confined to a height of less than 2 m on the trunks of standing trees. Sometimes, though, they occur to a height of 3.5 m. Attacked trees have large reddish to whitish pitch tubes on the bark surface (fig. 162) and whitish pitch and bark pellets in the bark crevices or at the base of the tree. Infested trees are almost always secondarily attacked by ambrosia beetles, which produce piles of fine white sawdust around the base of the tree.

F-532017

Figure 161.—Adult of the black turpentine beetle, *Dendroctonus terebrans*.

F-519568

Figure 162.—Pine tree attacked by the black turpentine beetle, *Dendroctonus terebrans*. Pitch tubes are reddish to white at first but soon assume a grayish hue.

Before 1949, the black turpentine beetle was thought of as a stump-infesting scavenger or, at most, as a species that killed patches of bark on apparently healthy pines. The first evidence of its widespread killing of trees occurred during an outbreak from 1949 to 1951 in Louisiana, when tens of thousands of cubic meters of lumber and thousands of cubic meters of pulpwood were killed. Since then, severe infestations on slash, longleaf, and loblolly pines have been reported from Florida, Georgia, Alabama, Mississippi, and eastern Texas. Losses in turpentine orchards have been severe. Heavily infested trees yield little resin and usually die within a few months. Losses of unprotected seed trees and losses in seed orchards also may be severe. Pitch and Austrian pines of landscape value have been killed on Cape Cod, Massachusetts.

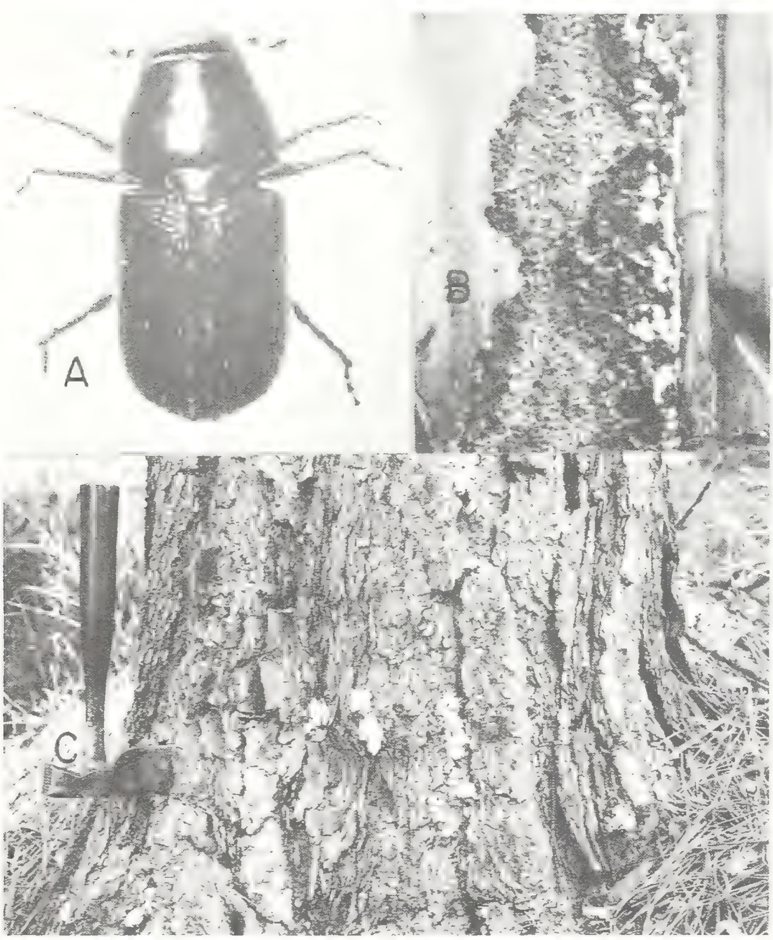
Some degree of natural control may result from the feeding activity of engraver beetles, wood borers, weevils, and termites which compete for the food of the beetle larvae. In low-lying areas, considerable brood mortality also occurs during periods of flooding. Losses may be prevented or reduced by minimizing damage to residual trees during logging operations, particularly in wet weather, or by rapidly salvaging recently infested trees. Where the salvage of infested trees is not practicable, they can be sprayed to kill the broods *(1119)*.

The **red turpentine beetle**, *D. valens* LeConte, the largest species of the genus, occurs in southern Canada, all the coniferous forests of the continental United States except in the south Atlantic and Gulf Coast States, and Mexico. It attacks all

species of pine within its range, and occasionally spruce, fir, Douglas-fir, and larch. The adult is light reddish-brown to dark brown and from 5.5 to 9 mm long (fig. 163A). Full-grown larvae are grublike, legless, 10 to 12 mm long, and white except for a brown head and small brown area at the rear. Mature larvae have a row of small, pale-brown tubercles along each side of the body. The adult is frequently confused with lighter specimens of the black turpentine beetle, especially where the ranges of the two species overlap.

The habits of the red turpentine beetle are very similar to those of the black turpentine beetle. It, too, usually attacks trees of reduced vigor, but can attack apparently healthy trees. Individual trees or groups of trees and fresh stumps are attacked most frequently. However, destructive populations may also develop in trees disturbed by logging, fire, or land clearing. Injured trees around construction sites or adjacent to piles of fresh lumber are infested frequently. Trees of pole size or larger are most susceptible *(1115)*.

In the colder parts of the insect's range, the winter is spent chiefly in the adult stage but, to some extent, in the larval stage. In the warmer parts of its range, adults fly intermittently during the warmer winter months. Attacks on standing trees are initiated by females boring through the bark to the wood, usually in the basal 2 m of the tree, but sometimes to a height above 3.5 m. Like those of the black turpentine beetle, these attacks are characterized by the presence of pitch tubes on the bark (fig. 163C). The gallery first runs horizontally or slightly upward, then it turns downward. When the attack is made just above the ground line, the gallery may be continued below ground line along a large root. A fully developed gallery may be 1



F-494425, 494422, 494420

Figure 163.—Red turpentine beetle, *Dendroctonus valens*: A, adult; B, gallery with mass of eggs along the side; C, pitch tubes at base of pine.

cm to more than 3 cm wide and up to 1 m or more in length. Eggs are laid in one or more elongate masses along the sides of the gallery (fig. 163B). The larvae feed gregariously away from the gallery in the phloem. Their feeding may kill a patch of inner bark ranging from a few centimeters to more than 30 cm wide. Pupation occurs in separate cells located between the bark and wood, either in the gallery or a short distance forward into fresh inner bark. Adults emerge through holes chewed through the bark; sometimes several use the same hole. In southern latitudes and at lower elevations, there may be two or three generations per year. Farther north and at higher elevations, there may be only one generation per year or every 2 years.

In areas where lumbering is continued for several years, the red turpentine beetle often becomes very abundant. The sudden discontinuance of these operations, therefore, may lead to attacks on healthy trees, causing catfaces and the killing of decadent trees in the stand. Shade tree pines in areas of new construction are also attacked and may be weakened or killed. Damage can be reduced or prevented by avoiding damage to trees or stands, deep earth fills over roots, or piling lumber of green logs near trees. It is also helpful to debark or spray freshly cut stumps with insecticide and to cut and remove pines dying from other causes. Watering or fertilizing individual trees also increases their resistance.

The **spruce beetle**, *D. rufipennis* (Kirby), occurs throughout the spruce forests of America, and breeds in native spruces. The adult is bicolored (black with red-brown elytra) or uniformly black and from 4.5 to 6.2 mm long. Normally, windfalls, prostrate dying green trees, and overmature or weakened standing trees over 20 cm d.b.h. are attacked. During epidemics, however, almost all trees are attacked regardless of size or vigor. Attacks usually begin on the lower third of the bole except for the first 60 to 90 cm above the ground. Later in the season, they are continued upward and downward, exclusive of limbs and parts of the trunk less than 20 cm in diameter.

Females construct vertical, almost straight egg galleries in the phloem, engraving the wood. Eggs are deposited in groups along the side of the gallery. After the eggs are laid, the attacking adults may vacate their galleries and construct new ones in the same tree or in nearby trees. The larvae may feed gregariously for the first two instars and individually for the last three instars. Pupation occurs in cells at the end of larval tunnels and the winter is spent in the bark in either the larval or adult stage. Signs of attack are red boring dust and pitch tubes on the bark, fading and dropping needles, and the reddish appearance of the twigs after the needles drop.

Several major outbreaks have occurred in eastern forests. One, from 1897 to 1901, killed more than 5.7 million cubic meters of valuable spruce in northern New England and eastern Canada *(591)*. The underlying causes of outbreaks are not well understood, but piles of slash in mature stands are believed to trigger outbreaks *(1181)*. Some degree of control is possible by cutting infested trees in the fall and removing them from the woods before spring, or by storing the logs in water.

The **eastern larch beetle**, *D. simplex* LeConte, occurs in the Northeastern States south to West Virginia and west to Minnesota. It also occurs from coast to coast in Canada and northwestward to Alaska. Its preferred host is tamarack but it has also been recorded from red spruce. Adults are dark brown, the elytra often having a reddish cast, and are from 3.4 to 5 mm long.

Winter is spent as young adults or larvae in the brood galleries. Adults are active from May until late August. Eggs are deposited in alternate groups of three to six each in niches arranged along the sides of longitudinal, sinuate galleries. The larval mines are in the inner bark and are quite short. Adults may reemerge and construct

several additional galleries during the season. Up to three generations may be produced annually. The first of these reaches maturity by midsummer and the second, by mid-September. The third brood spends the winter as larvae or young adults.

The eastern larch beetle generally infests dying or injured trees. However, during the 1970's, thousands of apparently healthy tamarack were killed in the Adirondack and Green Mountains. In many stands almost all larches more than 10 cm d.b.h. were killed. Plantations of European larch at Wanakena, N.Y., also suffered losses.

The **lodgepole pine beetle**, *D. murrayanae* Hopkins, is known from the Great Lakes region where it attacks stumps and the root collar of injured, windthrown, decadent or dying jack pine. Occasionally it infests red or eastern white pines. In the Rocky Mountain region of the West, this species has periodically been a serious killer of apparently vigorous lodgepole pine. Tree killing by *D. murrayanae* is often mistakenly attributed to the better known spruce beetle, which this species very closely resembles *(1353)*. Like some spruce beetles, adults are distinctly bicolored, having reddish-brown elytra and black bodies. It is most easily differentiated from the spruce beetle by its host and by the habit of the larvae to continuously feed in contact with one another rather than construct isolated feeding tunnels.

The **Allegheny spruce beetle**, *D. punctatus* LeConte, attacks stumps and the root-collar region of weakened or dying white and red spruces. This species is infrequently collected and apparently rare. It can be distinguished from the closely related *D. rufipennis* and *D. murrayanae* by its uniformly brown or dark-brown body covered with orangish, rather than pale-yellow, setae. Little is known about the biology of this species.

The genus *Phloeotribus* is represented by a number of eastern species, all but one of which breed in deciduous trees. The adults are distinguished from other bark beetles by the loosely jointed antennal club, all three parts of which are extended on the inner side into a leaflike process. They breed in dead or cut material or in weakened or dying trees. Young adults burrow into the bark of living trees during the fall where they spend the winter. Their burrows often extend into the outer part of the living bark, causing irritations which result in abnormal growths. These may show up as swellings on the trunks of a badly infested tree. Trees that harbor overwintering aggregations are not killed, but they may be seriously weakened.

Phloeotribus frontalis (Olivier) breeds in mulberry and is believed to occur wherever its host grows in the Eastern United States. Adults are brown and about 2 mm long. The branches and trunks of living trees or the trunks and stumps of killed trees are preferred for breeding. The gallery system consists of two short and deeply engraved branches extending transversely from the entrance hole. Aggregations of adults overwintering in bark of healthy trees may kill patches of bark, which are later sloughed.

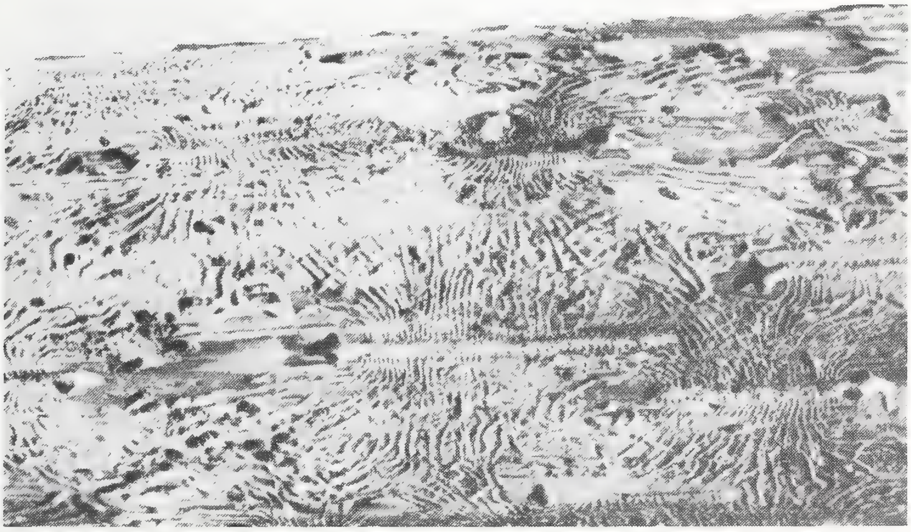
Phloeotribus dentifrons (Blackman) breeds in hackberry in the South and in the Midwest. Adults are dark brown to black and 1.5 mm long. Injured or dying limbs are preferred as breeding material. Girdled or weakened trees or green logs are also attacked if the bark is fairly smooth and not too thick. Many of the adults of the fall generation spend the winter in their burrows. Others may emerge, then bore into the bark of living trees to hibernate. Adults overwintering in their burrows often obliterate the gallery patterns during their prolonged periods of feeding under the bark.

The **peach bark beetle**, *P. liminaris* (Harris), occurs in southern Canada and from New Hampshire to Michigan and south to the Gulf Coast in the Eastern United

States where it attacks cherry and other stone fruit trees. Breeding attacks sometimes kill defoliated forest trees *(1071)* and aggregations of overwintering adults may damage orchard trees by killing patches of bark. Adults are light brown to nearly black, feebly shiny, sparsely clothed with long, fine, whitish hairs, and from 1.5 to 2.2 mm in length. The habits of the species are similar to those of *P. frontalis* except that the galleries tend to be somewhat more irregular.

The genus *Phloeosinus* is represented in North America by 27 species, 5 of which occur in eastern forests *(122)*. They breed preferably in cut, broken, or decadent conifers. The adults construct short, longitudinal egg galleries between the bark and wood. Newly emerged adults feed briefly before attacking a new host. Sometimes they clip off and eat young leaflets on healthy trees. Generally, however, they bore into the twigs. This occasionally causes the twigs to wilt, die, break, and drop to the ground.

Phloeosinus dentatus (Say), the **eastern juniper bark beetle**, occurs from New Hampshire to Georgia and westward to Texas and Nebraska. Its most common host is eastern redcedar, but it also attacks northern white-cedar. The adult, piceous-brown to black, is clothed with rather abundant short, gray hairs, and is 2.2 to 2.8 mm long. Eggs are laid in short galleries that extend upward from the entrance hole. The larvae mine for short distances across the grain, then upward with the grain (fig. 164). Infestations are usually found in cut, broken, or fire-damaged trees. Attacks have been reported on living, overtopped redcedars infested with the root rot fungus, *Fomes annosus* (Fr.) Karst, in North Carolina. Neither the insect nor the fungus working alone usually kills trees. Working together, however, they kill trees of all sizes *(76)*. Cutting and burning infested branches and keeping the trees in a healthy condition should be helpful in control.



Courtesy Duke Univ. Sch. For.

Figure 164.—Egg galleries and larval mines of *Phloeosinus dentatus*, the eastern juniper bark beetle, on trunk of eastern redcedar.

Phloeosinus taxodii Blackman, the **southern cypress beetle**, breeds in baldcypress and probably occurs wherever its host grows in the South. The adult is brownish black, has reddish-brown elytra, and is from 2.1 to 3 mm long. Logging slash and the larger limbs and trunks are especially attractive for breeding purposes. The galleries, and the larval and adult feeding habits are similar to those of the eastern juniper bark beetle. Because it apparently does not attack and kill living trees, the species is of minor importance.

The other three species of *Phloeosinus* occurring in eastern North America are: *P. canadensis* Swaine—on eastern redcedar and northern white-cedar in eastern Canada and from Maine to the Lake States; *P. pini* Swaine—on various pines and spruces in the Lake States and southern Canada; and *P. scopulorum neomexicanus* Blackman—on juniper and cypress in Texas.

The genus *Chramesus* is represented in the East by four species of stout, strongly convex, "humpbacked" beetles, less than 2 mm long. They are further distinguished by their large, elongate-oval, unsegmented antennal clubs and the five-segmented antennal funicle attached to the side of the club. They breed in broken or dying twigs and small limbs. The adults construct longitudinal or transverse unbranched egg galleries, partly in the bark and partly in the sapwood. *C. hicoriae* attacks various species of hickory throughout the Eastern States and in eastern Canada. *C. chapuisi* LeConte attacks hackberry from Pennsylvania to Florida and Texas *(120)*, and *C. subopacus* Schaeffer attacks hackberry in the Southern United States to Honduras. The fourth species, *C. wisteriae* Wood, attacks wisteria in Mississippi.

The genus *Carphoborus* is represented in eastern forests by at least two species. The adults are dark brown to black, more or less covered with short scalelike hairs, and are less than 2 mm in length. *C. bifurcus* Eichhoff is a fairly common species in the South where it breeds in dying, broken, and cut limbs of pines.

Polygraphus rufipennis (Kirby), the **four-eyed spruce bark beetle**, occurs in the spruce forests of the United States south in the Eastern States through the Appalachians. This dull dark-brown beetle, 2 to 3 mm long, can be identified easily by its completely divided eyes. Its hosts, in addition to the spruces, are larch, pine, and balsam fir. Infestations are usually found in slash and in dead and dying trees. However, when heavy populations develop in such material, nearby living trees are also subject to attack. The adult is dark brown to black and about 2.3 mm long. Eggs are laid in the sides of three to five irregular, short galleries that radiate away from a central nuptial chamber. The bark, but not the wood, is slightly engraved.

Subfamily Scolytinae

The genus *Scolytus* is represented in eastern North America by a number of species of true bark beetles, several of which are of economic importance *(119)*. Most species feed in twigs or buds of a host species while in the process of seeking a weakened host in which they can breed. All species except one breed in deciduous trees, and two species have been implicated in the transmission of Dutch elm disease. The adults differ from other eastern bark beetles in having the outer angle of the foretibia produced into a curved hook and the ventral surface of the abdomen ascend abruptly to the rear. In some cases the abdominal declivity is concave and ornamented by spines, tubercles, etc.

The **smaller European elm bark beetle**, *S. multistriatus* (Marsham), one of the two principal American vectors of the Dutch elm disease fungus, *Ceratocystis ulmi* (Buisman) C. Moreau, was first observed in North America in 1909 at Boston, Mass. *(202)*. Since then, it has spread over most of the United States and into southern Canada. Its hosts include all species of elm *(Ulmus)* and the related Japanese zelkova, *Zelkova serrata*. Adults are 2 to 3 mm long and distinctly two-toned with the elytra red-brown and the other parts black. Males have a bright yellow brush on the front of the head. The underside of the posterior is concave and armed with a stout spine projecting from the anterior margin of the second abdominal sternite (fig. 165A). The larvae are typical legless grubs about 3 mm long.

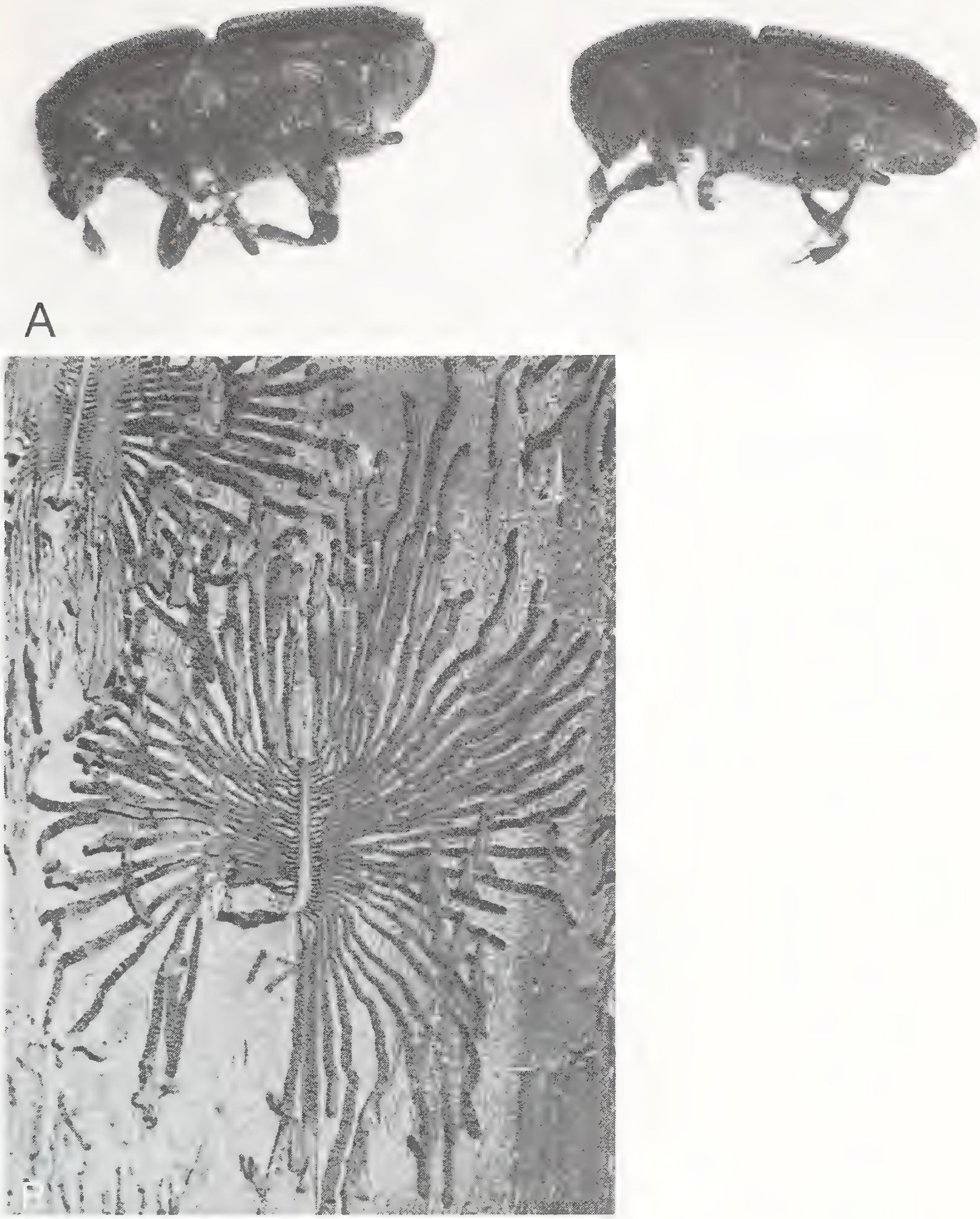


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Figure 165.—The smaller European elm bark beetle, *Scolytus multistriatus*: A, adults (male on left, female on right); B, gallery pattern.

Larvae overwinter in pupal chambers in the bark. Pupation occurs at the onset of warm weather in the spring and adults emerge through "shot holes" they chew through the bark at about the time the first elm leaves are fully expanded (late March to early June, depending on the latitude). Emerging adults fly directly to weakened or diseased elms to breed in the inner bark or to healthy elms where they feed in twig crotches. It is during twig feeding by contaminated beetles that healthy trees are inoculated with spores of the Dutch elm disease fungus. Chances of infection are greatest in the spring and early summer when the long vessels of the tree are functioning and near enough to the surface for the beetles to cut them while feeding.

Breeding attacks begin in material that is weakened by drought, disease, or injury. The bark of any wood recently cut from a living elm may be colonized. Attacks may quickly spread to undiseased parts of the tree and to adjacent healthy elms. Rapid death of entire trees or sections of trees and the retention of shriveled brown leaves indicate mass attack and successful colonization by the beetles, although beetles may also colonize material after leaves have wilted and been shed. Trees that are vigorously attacked emanate a sticky liquid that attracts ants, yellow jackets, and certain moths. Bark that has been removed or dried to the point of cracking will not be infested. Females initiate attack and release an aggregating pheromone that attracts both sexes to the breeding site. After mating near the entrance of their attacking tunnels, females bore egg galleries 2.5 to 8 cm long, engraving the surface of the wood, parallel with the grain (fig. 165B). Eggs are deposited in niches along the sides of the gallery. The larvae feed in the inner bark and the surface of the wood, angling away from the gallery. When fully grown, they form cells in which to pupate in the bark. During the spring and summer, the life cycle may be completed in 35 to 40 days. The spring-flying adults produce a generation that emerges from mid-June to mid-August, depending upon the latitude. Most of the progeny of the summer-flying adults enter a developmental diapause and overwinter, but a portion continues to develop and emerges in the fall.

The vertical orientation, the unbranched condition, and the engraving of the sapwood by both adults and larvae distinguish the gallery system of this species from the branched horizontal galleries of the native elm bark beetle.

Because of its role in the transmission of Dutch elm disease, the smaller European elm bark beetle has been the subject of considerable research, and huge expenditures have been made to eradicate or control it. Eradication efforts proved futile, but progress has been made on its control. The fundamental mode of controlling the size of the elm bark beetle population is limiting their supply of breeding material *(1287)*. Elm firewood, broken limbs, and severely stressed trees as well as elms that have Dutch elm disease should be eliminated or treated with an insecticide. In addition to the physical removal and burning or burying of infested or potential beetle breeding material (sanitation), diseased or unwanted elms can be rendered unsuitable for beetle breeding by the trap tree technique based upon injection of certain herbicides that cause the bark to dry before larvae are fully developed *(943)*.

Beetles that escape sanitation can be lured away from elms and killed on sticky traps baited with a synthetic copy of their aggregation pheromone *(716, 971)*.

An integrated approach that employs a medley of techniques to manage the elm, the bark beetles, and the fungus is most effective in reducing losses to Dutch elm disease.

Further information on control of elm bark beetles and Dutch elm disease is available *(688, 715, 717, 718)*.

The **larger shothole borer**, *S. mali* (Bechstein), also introduced from Europe, has been recorded from southern Ontario and Quebec in Canada, and from Connecticut, Maryland, New York, New Jersey, Ohio, Indiana, and Pennsylvania. It breeds in moribund apple, cherry, and elm. During its dispersal phase it sometimes feeds in twig crotches of healthy trees and may be an occasional vector of Dutch elm disease. The very dark-brown adult is from 3.4 to 4.4 mm long, and is about one-half as wide as long. The elytra have the punctures arranged in regular strial and interstrial rows of nearly equal size. The abdomen is weakly concave ventrally. The fifth sternite is longer than the third and fourth combined and the elevation of

the posterior margin of the abdomen is lacking in the male. This species differs from other eastern *Scolytus* by its oblique second abdominal sternite. Dying and weakened limbs and freshly cut wood are preferred for breeding purposes. The gallery system is slightly larger but similar to that of the smaller European elm bark beetle. When fully grown, larvae bore cells into the sapwood where they overwinter and pupate in the spring. There is one generation per year *(972)*.

The **hickory bark beetle**, *S. quadrispinosus* Say, occurs from southern Quebec to Georgia, Alabama, and Mississippi and west to Minnesota, Kansas, Oklahoma, and Texas. Its range is probably coincident with the natural range of hickories. This species is a serious pest of hickories and has also been recorded feeding on butternut and pecan. The adult is stout, black, almost hairless, and 4 to 5 mm long. The venter of the male is deeply excavated. The third abdominal segment is armed with three spines; the fourth with one large median spine. The venter of the female is without spines.

Adults appear in early summer and feed for a short time at the bases of leaf petioles and on the twigs of hickory before flying to the trunks and branches of living trees where they construct rather short (ca. 3 cm), longitudinal egg galleries between the bark and wood (fig. 166). In thick-barked trees, the gallery may scarcely touch the wood; in thin-barked limbs it may occur almost entirely in the wood. Eggs are deposited in niches at each side of the gallery. The larvae feed across the grain until nearly fully grown, then they abruptly turn and mine parallel to the grain. Before reaching maturity they leave the phloem and bore into the bark where they construct cells in which to pupate. The winter is spent in the larval stage and pupation occurs in the spring. There is one generation per year in northern areas. In the South, there are normally two broods per year.

Courtesy Duke Univ. Sch. For.

Figure 166.—Galleries of the hickory bark beetle, *Scolytus quadrispinosus*, in phloem of hickory. Note short vertical egg galleries and fan-shaped larval galleries.

The hickory bark beetle is one of the most important insect pests of hardwoods in the Eastern United States *(76)*. During drought periods, outbreaks in the Southeast have killed large tracts of hickory timber. At other times, damage is generally confined to the killing of single trees or to portions of their tops. The foliage of infested trees or tree limbs turns red within a few weeks of attack. Control practices include felling infested trees and destroying the bark during the winter months, treating infested bark with insecticides, or storing infested logs in ponds. To be effective, this type of control should be conducted over large, natural units.

The **shothole borer**, *S. rugulosus* (Müller), an introduced species known to have been in the United States since 1878, now occurs throughout temperate North America. It breeds in most fruit trees, and uncommonly in mountain-ash, hawthorn, and elm. The adult is grayish black, and from 1.7 to 2.9 mm long. The elytra are covered with short hairs and are reddish brown at the apex. The venter is unarmed and more gradually ascending than in other *Scolytus* that occur in North America. Because of its preference for broken, cut, or dying material, this species is of minor economic importance in forestry. However, the shothole borer is an important horticultural pest because populations that build up in pruned limbs and culled trees kill buds, limbs, and sometimes entire trees. Twig and bud damage results from adults feeding; branches are killed when they are mass attacked and colonized. Egg galleries are somewhat irregular but generally are parallel with the grain. Larvae mine the cambial region and pupate there during summer months. Larvae that mature in the fall generally bore cells into the sapwood where they overwinter and then pupate in the spring. There are one to four generations per year, depending on locality. A parthenogenic race occurs in Israel *(508)*.

Scolytus fagi Walsh breeds in beech and hackberry from Illinois to Texas. Adults are 4.5 to 5 mm long. The elytral striae are distinctly impressed, and the strial punctures are much coarser than those of the interstrial rows. The species is of slight economic importance.

The **hackberry engraver**, *S. muticus* Say, occurs from North Dakota and Pennsylvania to Texas and Florida, and breeds in dying and dead limbs of hackberry. The adult is reddish brown to black, and from 4.5 to 7.5 mm long. There are long, ashen hairs on the elytra and sides of the pronotum. Egg galleries are similar to those of the hickory bark beetle. The larvae feed first between the bark and wood; later they burrow into the wood where they pupate. There are two generations per year in the Deep South and one per year in the Lake States.

Scolytus piceae (Swaine), the **spruce scolytus**, occurs from Alaska and Nova Scotia to California and New York approximately coincident with the range of white and Englemann spruces. It breeds in all spruce species within its range; reports of spruce scolytus in larch and balsam fir represent aberrant occurrences or errors. Adults are readily distinguished from other eastern members of the genus by a ventral spine that arises from the center rather than the anterior margins of the second abdominal sternite. The unique burrows of this species typically consist of two and sometimes three egg galleries extending across the grain from a central nuptial chamber. Broken limbs and tops are preferred breeding material.

Members of the genus *Pseudothysanoes* are closely related to those of the genus *Thysanoes*. They differ, however, by breeding in the bark instead of the wood of their hosts. *P. lecontei* Blackman attacks various oaks, hackberry, hophornbeam, chestnut, and walnut from New York to North Carolina. The adult is dark brown, shiny, and about 1.2 mm long. *P. rigidus* (LeConte) breeds in basswood from Canada to Michigan, Ohio, and West Virginia.

Pseudothysanoes dislocatus (Blackman) is brown and about 1.3 mm long. The head is slightly concave at the middle, with a row of long hairs at the lower margin of the concavity. The antennal funicle is six-segmented, the club unsegmented, and the scape armed with long hairs. It constructs its galleries just beneath the bark of twigs of its hosts. It has been recorded from hickory from West Virginia to Florida.

The genus *Pityogenes* contains a number of species, all of which breed in the twigs, limbs, and thin-barked portions of the boles of pines. Some species prefer to breed in slash, whereas others most commonly attack decadent lower limbs of living trees. Vigorous trees are usually not attacked except in heavily infested areas. Trees weakened by drought or transplanting, or by ground fires or mechanical means, are frequently attacked and killed. Adults are usually stout and sparsely pubescent. The antennal funicle is five-segmented, and the antennal club is flat and sutured on both sides. The elytra are marked with rows of punctures, excavated, and ornamented with teeth at the posterior end. Females of all species except *P. meridianus* Blackman have conspicuous cavities in the front of their heads. Males have three slightly enlarged to very enlarged spines on each side of the elytral declivity. Attacks are initiated by the males which are joined by two to seven females. The gallery system is usually engraved on the surface of the wood and consists of several egg tunnels radiating from a central nuptial chamber.

Pityogenes hopkinsi Swaine is a common species wherever its host, eastern white pine, occurs in eastern North America. Rarely other pines and spruces serve as hosts. In early spring, overwintering adults infest winter-pruned limbs and other white pine slash. A summer generation attacks trees weakened by basal canker or blister rust or joins the pine engraver or the red turpentine beetle in attacking stressed trees. Logging slash may be infested any time when adults are active. *P. hopkinsi* concentrates its attacks in the smooth-barked portions of the tree, thereby limiting competition with the pine engraver, which infests areas with fissured bark. The insects are 1.8 to 2.1 mm long. The male has three similar teeth on the elytral declivity; the female has large frontal fossa.

Pityogenes meridianus Blackman is known to occur in North Carolina and Mississippi. It breeds in slash and the dead and dying lower branches of pines weakened by shading or injured by ground fires. The adult is dark reddish-brown and from 2.7 to 3 mm long. Males have a large, blunt, downward curving spine at the upper margins of the elytral declivity and two smaller, upward curved spines at the lower margin of the declivity. Females have no frontal fossa. Burrows consist of two to five galleries originating at and radiating away from a central nuptial chamber. The related species, *P. plagiatus* (LeConte), breeds in pines in the Atlantic States. The elytral declivity is similar to that of *P. meridianus* but the species are easily distinguished by the female's large frontal fossa that is divided by a vertical partition.

The genus *Pityokteines* is represented in the United States by several species, only one of which occurs in eastern forests. The beetles breed primarily in dying or felled trees, particularly firs and spruces. The eastern species, *P. sparsus* (LeConte), the **balsam fir bark beetle**, is frequently injurious to balsam fir, killing large groups of trees. Pine, spruce, and larch are also attacked. Infestations are found in logging slash in the limbs and tops of trees dying suddenly, in windthrows, and in weakened and perfectly healthy trees. The adult is about 2 to 3 mm long and is distinguished by long yellow hairs arising from the front of the head and from the apical margin of the pronotum. Eggs are deposited in large niches along the sides of several galleries that radiate away from a central nuptial chamber and scar the wood deeply. Larval tunnels are longitudinal and follow the grain of the wood.

The genus *Orthotomicus* is represented by one species in eastern forests. It is closely related to the genus *Ips*, but the adults differ in having obliquely truncate rather than flattened antennal clubs and feeble rather than well-developed teeth on the margin of a shallowly concave declivity.

Orthotomicus caelatus (Eichhoff) occurs throughout the East, Lake States, and eastern Canada. It commonly breeds in thick bark on stumps and logs or at the bases of weakened or dying pines, spruce, larch, and balsam fir. The adult is dark reddish-brown to nearly black and from 2 to 2.3 mm long. Short, radiating egg galleries originate at central nuptial chambers, and from one to six eggs are laid in large niches or pockets along their sides. Specimens of a morphologically closely related species, possibly a variety, have been collected from the twigs of fire-killed young loblolly pines in North Carolina, where they were apparently breeding as well as mining out the pith and wood. Adults were also reared from dry twigs and the tips of longleaf pine logging slash *(76)*.

Among the bark beetles, the genus *Ips* ranks next in importance to the genus *Dendroctonus* in its destructiveness to pines and spruces. Infestations normally occur in lightning-struck trees and those recently felled by windfalls, snow-breakage, and logging, and in road slash. However, when heavy populations develop in this material, the adults emerge and attack and kill adjacent groups of young healthy pines and the tops of older trees. Infestations in green timber are usually of short duration unless the trees have been weakened by drought, fire, or other disturbances. Spot- or group-killing in pulpwood or pole-size trees or, less often, in mature stands is characteristic of outbreaks. Widespread outbreaks occur frequently, and losses may be extremely severe. More than 3 million cubic meters of commercial timber and more than 1.8 billion cubic meters of pulpwood were killed in the South Atlantic and Coastal States during the period of 1952-55. It is estimated that annual losses of 765 million cubic meters of pulpwood are incurred in Florida alone. The North American species of *Ips* have been arranged into a number of taxonomic groups *(592, 593, 594, 595, 596, 597, 598, 599, 600)*.

The male initiates the attack by boring through the bark to the wood and constructing a nuptial chamber. Here he is joined by one or more females (typically three), each of which excavates an egg gallery in the phloem. These galleries radiate in all directions from the chamber through the phloem, but eventually tend to run parallel with the grain of the wood. The resultant pattern tends to form a rough Y or I shape. Eggs are deposited in small niches at irregular intervals along the sides of the gallery, and the larvae tunnel in the phloem until fully grown. Pupation occurs in cells hollowed out in the inner bark. Young adults feed for a short time beneath the bark and then emerge, several often using the same exit hole. In northern areas, the winter is spent in the adult stage under the bark of the brood tree or in the litter below the infested tree. In the South, winter may be spent in the bark in all life stages.

Ips calligraphus (Germar), the **six-spined engraver**, occurs through eastern America. Although it breeds in any species of pine available, its distribution in the Northeast coincides with that of pitch pine. Trunks, stumps, and large limbs of recently felled trees appear to be favored for breeding purposes, but the trunks of apparently healthy pines are also attacked, especially in the Southeastern States where it frequently attacks in concert with other *Ips* and *Dendroctonus* species. Attacks on living trees usually occur on the lower portions of trunks with diameters of 15 cm or more. In the South, this is one of the first species to attack drought-stressed trees.

The adult is dark reddish-brown to black and from 3.5 to 6.5 mm long. The declivity is deeply excavated and coarsely punctured. Each side is armed with six teeth, and the apical margin is strongly produced. The egg galleries, usually three to five, radiate from a central nuptial chamber and run longitudinally, grooving both the bark and wood (fig. 167). The larval mines are broad, tortuous, often long, and transverse. In the South, the life cycle may be completed in 25 days, and there may be 6 or more generations per year.

Ips grandicollis (Eichhoff), the **southern pine engraver**, occurs in eastern Canada and in the Eastern United States from Massachusetts to Minnesota, Nebraska, and Texas and south to Florida and Mississippi. Like *I. calligraphus*, it attacks any pine species available but its distribution north of the southern pine region is coincident with the distribution of pitch pine. Recently felled trees and slash are preferred, but the trunks and limbs of apparently healthy trees are also infested when attack occurs in concert with other bark beetle species. Heaviest infestations in large living trees are found on limbs and the upper portions of trunks. Spot- or group-killing of pines is characteristic of the species. During periods of extreme drought, these groups increase in size and abundance. Populations normally develop in areas of recent logging operations.

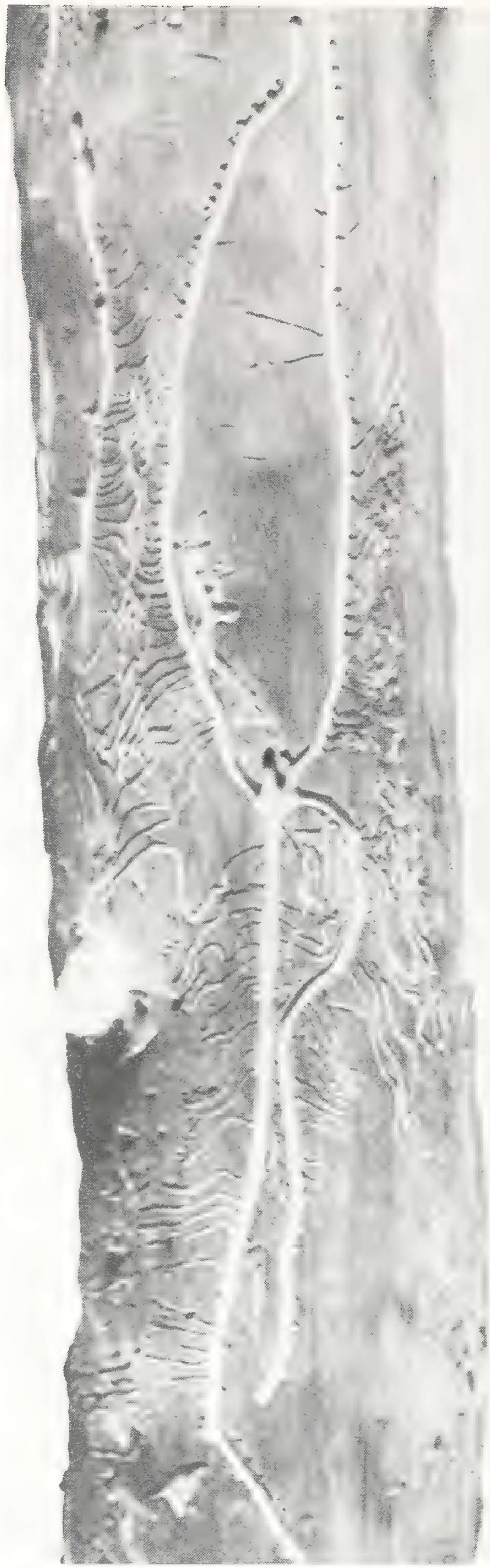
The adult is dark reddish-brown to black and from 2.8 to 4.7 mm long. The declivity is deeply excavated, coarsely punctured, armed with five teeth at each side, and the apical margin is strongly produced. The egg galleries, three to five, radiate from a central nuptial chamber and run longitudinally, grooving both the bark and wood (fig. 168). The larval mines are more or less transverse. In the South, the life cycle requires from 20 to 25 days, and there are 6 or more generations per year.

The **small southern pine engraver**, *I. avulsus* (Eichhoff), the smallest species of *Ips*, breeds in all species of pines from southern Pennsylvania to Florida and Texas. Thin-barked slash, such as the limbs and tops, is preferred but groups of young, vigorous trees and the tops of large, living trees are also attacked frequently and killed. Attacks on large trees are usually associated with attacks on the lower portions of the trunks by other species of *Ips* or *Dendroctonus frontalis*. Adults are attracted to freshly cut and injured trees. Any disturbance that causes pitch flow may induce attack. Spot-killing occurs at times among pines showing no evidence of previous injury or decreased vitality.

The adult is reddish brown to black and about 2.3 to 2.8 mm long. The declivity is shallowly excavated and deeply punctured. Each side is armed with four small teeth and the apical margin is slightly produced. Adults make one to several long winding egg galleries that originate from a central nuptial chamber (fig. 169). Larval galleries are short, transverse, and each ends in a pupal cell in the phloem. In the South, the life cycle may be completed in 18 to 25 days, and there may be 10 or more generations per year.

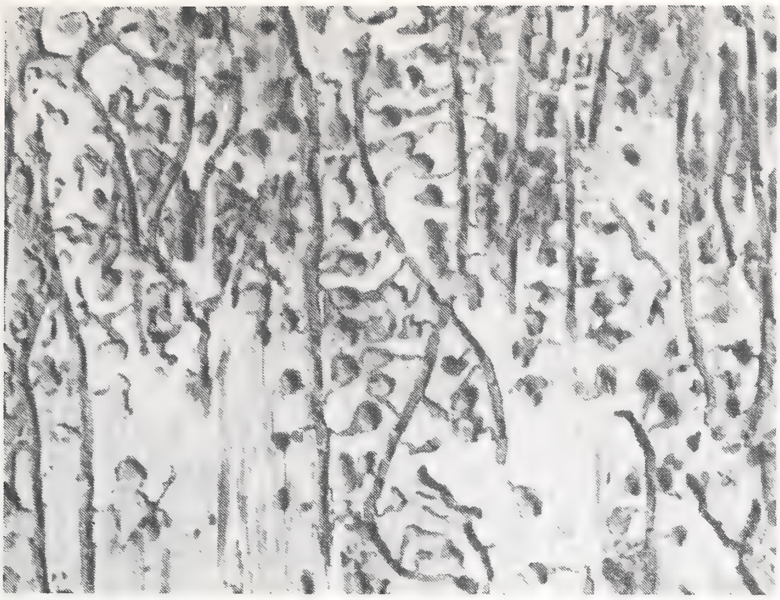
The **pine engraver**, *I. pini* (Say), occurs throughout most of the coniferous forests of North America except the Pacific Coastal forests, the southern pine forests, and Mexico. In the Eastern States it is ubiquitous in the north and extends south in the Appalachian Mountains to Georgia. It breeds in all species of pine and spruce within its range. Infestations usually develop in logging slash and windfalls or in trees dying of other causes. When heavy populations build up in this type of material, nearby healthy trees may be attacked and killed. Heavy infestations have occurred in cutover and burned-over areas in Canada.

Courtesy Duke Univ. Sch. For.
Figure 167.—Gallery of *Ips calligraphus* on limb of a shortleaf pine.



Courtesy Duke Univ. Sch. For.
Figure 168.—Gallery of the *Ips grandicollis*, southern pine engraver, on limb of loblolly pine. Note egg niches and incompleted larval mines.

The adult is brown to black, is from 3.5 to 4.5 mm long, and has four teeth on each side of the declivity. Egg galleries, from three to six, radiate away from a central nuptial chamber in the phloem, deeply scarring the sapwood. Larval tunnels extend a short distance in the inner bark and end in pupal cells. Adults remain under the bark for a short period before emerging. While there, they make irregular,



Courtesy Duke Univ. Sch. For.

Figure 169.—Galleries of the small southern pine engraver, *Ips avulsus,* in bark of shortleaf pine. Note radiating tunnels of adults, short larval mines, and pupal chambers.

meandering food tunnels, deeply engraving the wood. Winter is spent in the adult stage on the ground. There appears to be three generations per year as far north as Wisconsin *(1065)*.

Other less common eastern species of *Ips* include: *I. perturbatus* (Eichhoff), the **northern spruce engraver**—breeds in white spruce in the Lake States and Canada; *I. perroti* Swaine—breeds in red and jack pines in Minnesota; *I. borealis* Swaine, the **northern engraver**—breeds in white spruce in Maine, Canada, and the Lake States; *I. latidens* (LeConte)—breeds in eastern white, red, jack, and Scotch pines; rarely in white spruce; and hemlock in New York, the Lake States, and adjacent parts of Canada.

Lymantor decipiens (LeConte) occurs from Michigan and Quebec to Kansas and Mississippi. The adult is reddish brown and about 1.7 mm long. The antennal funicle is four-segmented, the club sutured on both sides and slightly longer than wide. It breeds in dead dry limbs, sprouts, and seedlings of living hickory, maple, and apple. Its burrows are constructed in the wood, usually just beneath the bark but sometimes deeper. The adults and larvae reportedly feed on certain black wood fungi that are always present in the dead wood.

The genus *Dryocoetes* is represented in North America by seven species, five of which occur in eastern forests *(151)*. They usually breed in the upper portions of trunks, in the roots of injured or dying trees, or in windfalls. Both coniferous and deciduous trees are attacked.

Dryocoetes affaber (Mannerheim), the most common North American species, occurs throughout the spruce forests of the continent north of a line from North Carolina to New Mexico. Spruces are preferred hosts, but pines and larches are also attacked. Infestations occur in felled trees, stumps, and the trunks of standing trees. The female adult is reddish brown to black, has the frons pubescent, and is from 2.5 to 3.3 mm long.

Dryocoetes autographus (Ratzeburg) is widely distributed in the coniferous forests of North America. Infestations are usually found at the base and in the roots of dying or injured standing trees, or in stumps or felled trees. A wide variety of

trees are attacked including spruce, hemlock, Fraser fir, and pine. There have also been reports of infestations in yellow-poplar. The adult is from 3.5 to 5 mm long. It differs from the adults of all other species in the genus in having a distinctly punctured pronotal disk, a convex declivity with the sutural interspace only slightly raised, and in the absence of a dense mat of hair on the female frons.

The **birch bark beetle**, *D. betulae* Hopkins, occurs from coast to coast in Canada and south to Florida and Mississippi in the Eastern States. Its hosts are recorded as birch, beech, sweetgum, cherry, and pear. Attacks are generally confined to dead and dying trees, logs, and stumps. The adult female is reddish brown, has a dense mat of hairs on the frons, and is from 2.8 to 4.5 mm long.

Dryocoetes caryi Hopkins occurs throughout the northern coniferous forests and south to North Carolina in the Eastern States. Its hosts are white, red, and Engelmann spruces. Infestations are usually confined to the trunks of small, weakened, shaded-out, suppressed trees. The female adult is reddish brown and from 2.1 to 2.7 mm long.

Dryocoetes granicollis (LeConte), a rather rare species, breeds in spruce from Quebec to North Carolina. The female adult is reddish brown and from 2.3 to 3 mm long.

The genus *Crypturgus* is represented in eastern forests by three common species, none of which is economically important. The adults are brown or black, about 1 mm long, and are found in the inner bark of dead or dying conifers. Their short, irregular burrows usually originate from the burrows of larger bark beetles, but sometimes from ventilation holes made by *Monochamus* spp. *C. alutaceus* Schwarz, the smallest of all North American bark beetles, occurs from New Jersey to Florida. It breeds in species of pine, and in black and Norway spruces. *C. borealis* Swaine breeds in various conifers from Maine to Pennsylvania. *C. pusillus* (Gyllenhal), a species introduced from Europe, attacks pine, spruce, balsam fir, and larch in eastern Canada and from Maine and New York to West Virginia and the Lake States.

The genus *Pseudopityophthorus* is closely allied to *Pityophthorus*, but differs in that the adults have a longer and more acute prosternal process *(118)*. The first segment of the antennal club also is longer than those in *Pityophthorus*, and the males rather than the females have long, yellowish hairs on the front of the head. The majority of species prefer to breed in the inner bark of recently cut or dying limbs of various species of oaks. A few species attack other tree species, and some attack and kill perfectly healthy limbs.

Pseudopityophthorus minutissimus (Zimmermann), the **oak bark beetle**, a common and widely distributed species from Quebec and Massachusetts to Georgia and westward to Mississippi and Colorado, breeds in various species of oaks and occasionally in many other hardwoods. The adult is dark reddish-brown, from 1.5 to 1.9 mm long, and can be distinguished from other species in the genus by the reticulate frons and pronotal disk in both sexes. In the southern portions of its range, it is active throughout the year, and there are at least two generations per year as far north as the Lake States. Eggs are laid in circumferential galleries in branches from 12 to 100 mm in diameter and the larvae tunnel away from the gallery, following the grain of the wood. When the adults emerge, they fly to the tops of the trees and feed on the buds, in twig crotches, in the axils of leaves, and in immature acorns. Because of these habits and because of the abundance of the species in stands suffering from oak wilt disease, this species is strongly suspected of playing a primary role in the transmission of the fungus *(168)*.

Other common eastern species of *Pseudopityophthorus* are: *P. pruinosus* (Eichhoff)—breeds primarily in dead and dying oaks; also in beech, American hornbeam, hickory, maple, and hophornbeam. Smooth-barked branches in the upper parts of standing trees are preferred, but slash and other recently felled material also are attacked. The adult is dark brown and about 1.5 to 1.8 mm long. This species also is suspected of transmitting oak wilt fungus *(1023)*. *P. pubescens* Blackman—breeds in various oaks, American hornbeam, and chestnut in the Southeast. The adult is dark brown, about 1.8 mm long, and the male has rows of very long hairs on the elytra. *P. asperulus* (LeConte)—breeds in various species of oaks, chestnut, and gray birch from Maine to Florida and Texas. The adult is dark reddish-brown and from 1 to 1.5 mm long.

The genus *Cryphalus* consists of small, dull, dark-brown to black beetles about 2 mm or less in length. They usually breed in small, suppressed trees but may also be in twigs, branches, and seedlings. *C. fraseri* Hopkins attacks Fraser fir in the Southern Appalachians and balsam fir throughout the Northeastern States and in eastern Canada. *C. ruficollis* Hopkins is found commonly in red and white spruces in Maine and New York. *C. rubentis* Hopkins has been collected from red spruce in West Virginia.

The genus *Pityophthorus* is represented by more than 100 species in North America, many of which occur in eastern forests. The majority of species breed in the inner bark and central pith of twigs or small branches, but a few may be found in larger material. Most species utilize conifers, especially pines; a few species attack broadleaf trees.

Gallery systems usually consist of 2 to 4 egg tunnels radiating from a central nuptial chamber, although the pith-feeding species construct an unbranched system. All species deposit eggs individually in niches. Material colonized by *Pityophthorus* is usually unthrifty, cut or broken, except that certain pith-feeding species may bore into healthy twigs.

Despite its pervasiveness, this group of insects causes little economic injury except killing of twigs on drought-stressed saplings, and infesting scions on special grafted planting stock.

Adults are very small (1.3 to 2.0 mm long), shiny, and have a distinct elytral declivity that may be armed with tiny spines. Females usually have a frontal brush of yellow hairs while males do not *(115, 116)*. Identification of species in this difficult genus is usually a task for experts. Detailed information on *Pityophthorus* can be found in a generic revision *(154)* or in a monograph on the North American Scolytidae *(1356)*.

Pityophthorus lautus Eichhoff breeds in redbud, sumac, and a variety of other hosts from Minnesota and Quebec to Missouri and North Carolina. *P. liquidambarus* Blackman breeds in sweetgum, probably throughout the natural range of this tree. *P. crinalis* Blackman breeds in poison-sumac and *P. scriptor* Blackman breeds in staghorn sumac.

Pityophthorus pulicarius (Zimmermann) occurs throughout the Eastern United States and in eastern Canada. It attacks all species of pines in its range and has also been recorded from deodar cedar. Infestations occur in the wood and pith of twigs of dead and dying trees, in small trees scorched by fire, in slash, and in 1-year-old cones of felled pines. Scions of grafted slash pines being prepared for seed orchard establishment in Florida have been seriously injured.

Additional eastern species of *Pityophthorus* and their hosts are as follows: *P. opaculus* LeConte—eastern white pine, tamarack, balsam fir, and various spruces

from Maine to West Virginia and west to California; *P. biovalis* Blackman—various spruces and pines in New York, Maine, and Michigan; *P. balsameus* Blackman—balsam fir, spruces, and pines from Michigan to Maine and south to North Carolina; *P. dentifrons* Blackman—red and white spruces from Minnesota to Maine and North Carolina; *P. cariniceps* LeConte—balsam fir, pines, and spruces in the northern tier of States and southern Canada; *P. annectens* LeConte—living trees and slash of various pines from West Virginia to Florida and Texas; *P. intextus* Swaine—white and red spruces from British Columbia to Newfoundland in Canada south to West Virginia; *P. pulchellus* Eichhoff—probably all species of pines from Maine to North Carolina and Texas, also red spruce and balsam fir; *P. puberulus* (LeConte)—all species of conifers from British Columbia to New Brunswick in Canada to Kansas, Texas, and Florida; and *P. ramiperda* Swaine—red and eastern white pines in eastern Canada and from Maine to the Lake States.

The genus *Pityoborus* contains only one eastern species, *P. comatus* (Zimmermann). It is widely distributed in the Southeastern States, but appears to be most common in the Mississippi area. Its known hosts are shortleaf, loblolly, longleaf, and slash pines. It breeds beneath the bark on the undersides of living but weakened branches of its host and is of little or no importance. Egg galleries radiate in any direction, deeply engraving the wood. The larvae construct wide, short, connecting galleries. The adult is brown to black with yellowish appendages and is about 1.8 mm long. The female is distinguished by the presence of a patch of fine, dense, silky hair on each side of the pronotum.

Cone and Seed Beetles
Spermophagous Scolytidae

The genus *Conophthorus*, which best exemplifies spermophagy (cone and seed feeding) in eastern North America, is very destructive to many species of pines *(547)*. The close relationship of *Conophthorus* with twig beetles of the genus *Pityophthorus* is indicated by their occasional infestation of new shoots.

Several tropical species that infest seeds of hardwoods occasionally are imported into North America. For example, *Hypothenemus obscurus* (F.) is frequently intercepted in shipments of Brazil nuts.

The adults of *Conophthorus* are stout, dark brown to black, and about 1.2 to 4 mm long. The female adult bores into a second-year cone at the petiole or base into the axis, where she constructs a small tunnel and deposits eggs at intervals in niches along its sides. The larvae feed on the scales, seeds, and tissues of the cone, often completely honeycombing the interior. Infested cones wither and die before reaching maturity. *Conophthorus* species usually attack one or a few pine species. If second-year cones are scarce, first-year cones and current-year shoots may be attacked. Another way in which these insects survive years in which few cones are available is that one portion of the population emerges from the infested cone after the first winter, while other brood adults remain dormant in the cones or in the litter until the second or possibly the third year. By periodically destroying a majority of the annual cone production of a species, cone beetles can delay restocking in logged or burned areas.

Cone beetles and other cone insects perennially destroy most of the seed produced. For satisfactory yields from seed orchards it is usually necessary to treat the trees with topical or systemic insecticides. Controlled burning or cleaning the ground in the fall or early spring should provide substantial relief from infestation since *Conophthorus* and most other cone-feeding insects overwinter in fallen cones or in the ground litter.

The **white pine cone beetle**, *C. coniperda* (Schwarz), occurs throughout the natural range of its host, eastern white pine, in eastern America. Apparently it rarely attacks cones of loblolly pine in Virginia *(1354)*. The adult is shiny black, from 2.8 to 4.2 mm long, and covered with moderately long, erect hairs.

Winter is spent in the adult stage in infested cones on the ground. These adults begin to emerge in late April and fly to the tops of nearby pines. When a female finds a suitable cone, she bores into the petiole or the base of the cone. A dark-reddish pitch tube marks the point of attack. Once into the cone axis, she bores toward the cone tip. A male joins her at this time and the tunnel is extended the full length of the cone (fig. 170). The larvae feed on the seed and tissues until full grown and then pupate in cells at the ends of the tunnels. Infested cones die and fall to the ground in mid to late summer. Some adults emerge during the fall but the majority remain in the cone until the following spring. Some of the fall-emerging individuals fly to the tops of pines and attack first-year conelets; the remainder stay on the ground where they feed on other infested cones. There is one generation per year.

F-505549

Figure 170.—Cone damage by the white pine cone beetle, *Conophthorus coniperda*.

This is one of the most destructive insect pests of eastern white pine seed. Entire seed crops in many stands in New England have been completely destroyed *(944)*. Most of the damage results from the killing of second-year cones; however, considerable damage also results from attacks on first-year conelets, shoots, and occasionally buds and male flowers.

The **red pine cone beetle**, *C. resinosae* Hopkins, occurs in southeastern Canada and the northern tier of States from Maine to Minnesota. It breeds by preference in

second-year red pine cones, but also attacks current-year red pine shoots and occasionally second-year jack pine cones. It is also found in cones of Virginia pine in West Virginia *(1356)*. The adult is shiny black, with sparse, short fine hairs and is about 3 to 3.5 mm long *(758)*.

Seasonal activity begins in May when the overwintering adults emerge and attack current-year shoots and second-year cones of red pine. The adults feed for a few weeks and then attack cones for oviposition purposes. Cones are entered by females near the petiole on the underside, often forming an open groove at the cone base. The tunnel is extended in the pith to the end of the cone. Eggs are deposited singly in niches along the sides of the tunnel. After oviposition is completed, the female returns to the base, fills the base of the tunnel with a plug of resin and debris, then vacates the cone. Infested cones soon wither, harden, turn brown, and occasionally drop from the tree. The larvae feed on seeds and scales in the cone and pupate in frass-lined cells which often are near the base. During late summer, new adults emerge either through the plugs in the bases of the tunnels or through the top or sides of the cones. Soon after emergence they bore into current-year red pine shoots and tunnel forward through the pith into vegetative buds where they spend the winter. There is one generation per year. Weakened at point of beetle entry, pine shoots soon break off and fall to the ground. Damage by *C. resinosae* is often severe enough to make the commercial collection of red pine seed impractical or impossible. Prescribed burning is recommended as a control technique for the red pine cone beetle *(855)*.

Conophthorus banksianae McPherson, the **jack pine tip beetle**, a species closely related to *C. resinosae*, also occurs in the Lake States and southern Canada. It breeds in the shoots of jack pine. The adults bore into the shoots about 25 mm below the bud then tunnel toward the bud, either to feed or to deposit their eggs. Ovipositing lasts from late May into mid-July. Winter is spent in infested buds, and there are two generations per year. Infested terminals are often killed, leading to multiple branching and flat-topping of infested trees. Damage to natural jack pine reproduction and in jack pine plantations is often severe.

Wood-Boring Beetles
Xylophagus Scolytidae

Genera of Scolytidae that feed on wood occur in both subfamilies (Hylesininae and Scolytinae). Xylophagus scolytids in eastern North America bore into moribund to dry dead twigs on various hardwood species. Mining by adults and larvae deeply scores the surface of the wood or is entirely within the wood. A rapid change in color and texture of the wood near the tunnels suggests that micro-organisms introduced by the beetles are important in nutrition of the beetles. Species with this feeding habit cause no economic loss.

Genera included here under this feeding habit include *Hypothenemus*, *Hylocurus*, *Micracis*, *Micracisella*, and *Thysanoes*. A few species of *Pityophthorus* may be truly xylophagus but this genus is grouped with the bark beetles because tunneling in the wood of twigs by some species appears to be incidental to their feeding in the bark and pith.

The genus *Micracis* contains a number of species that breed in the wood or pith of their hosts. Adults are similar to those of the genus *Hylocurus* but differ in having the first joint of the antennae flattened and ornamented with long hairs.

Micracis swainei Blackman, a widely distributed species in the South and Southwest, breeds in poplar shoots and in dead and dying twigs of redbud and

willow. The adult is brown and about 2.7 mm long. The terminal hook of the anterior tibia is strongly curved. *M. suturalis* LeConte breeds in the twigs and small branches of redbud, walnut, and willow.

The genus *Micracisella* includes certain species formerly included in the genus *Micracis (123)*. Female adults have the antennal scape flattened, somewhat extended laterally, and clothed with long hairs.

Micracisella opacicollis (LeConte) occurs from Minnesota and New York to North Carolina. It breeds in the pith of dead twigs, in sprouts, and in shoots of oak, maple, redbud, and baldcypress. The adult is dark brown to black and from 1.7 to 1.9 mm long. *M. nanula* (LeConte) breeds in oaks and redbud from South Carolina to Florida and Texas.

The genus *Thysanoes* is closely allied to the genera *Hylocurus, Micracis*, and *Micracisella*, but differs in having the apex of the elytra broadly rounded. *T. fimbricornis* LeConte breeds in the twigs of red and black oaks, maple, redbud, hornbeam, hackberry, hickory, and acacia from Pennsylvania to Florida and Texas. The adult is yellowish brown and from 1.6 to 1.9 mm long. Egg galleries are constructed almost entirely in the sapwood, nearly encircling the twig in a diagonal direction just beneath the bark. Larval galleries run parallel with the grain. The related species, *T. lobdelli* Blackman, has been observed breeding in oaks and maple in Mississippi, Florida, and Georgia, and *T. berchemiae* Blackman, in elm, oaks, and rattan-vine from Virginia to Florida and Texas.

The genus *Hylocurus* contains a number of species that rear their brood in the wood of their hosts. In attacking the host, the adults bore directly into the sapwood or pith, where they construct nuptial chambers. From each chamber, one to several egg galleries are then extended obliquely through the wood or in several directions through the pith. The majority of species are of minor importance since they normally breed in recently cut, dying, or dead limbs of their hosts. Adults are quite small, 3 mm or less in length. The head is concealed from above by the pronotum, which is strongly roughened in front; the first joint of the antennae is club-shaped; and the elytra are elongated and pointed at the apex.

Hylocurus rudis (LeConte) breeds in the twigs and branches of hickory, walnut, maple, and hackberry throughout much of the Eastern United States. The adult is dark brown to black and 2.2 to 3.0 mm long. *H. spadix* Blackman, *H. biorbis* (Blackman), *H. bicornus* (Blackman), and *H. harnedi* (Blackman) breed in hickory.

Hylocurus langstoni (Blackman) occurs in the South from the East Coast to Texas. It breeds in the limbs and trunks of dying or recently killed honeylocust, hackberry, mulberry, and slippery elm. Green poles and posts are also frequently attacked and damaged. The damage resembles that caused by powderpost beetles.

The genus *Hypothenemus* contains numerous species that breed in dying and dead twigs, dead bark, seeds, and hulls. Included in the genus are species formerly assigned to the genus *Stephanoderes*. A few of the seed-infesting species may be injurious at times.

Hypothenemus dissimilis (Zimmermann) is widely distributed in eastern America from Quebec to Florida and west to Michigan. It breeds in dying branches and dead twigs of various hardwoods such as the hickories, oaks, honeylocust, hornbeam, and redbud. The adult is dark brown to black and from 1.2 to 1.8 mm long. They bore deep entrance holes, and one or more elongate tunnels are constructed more or less parallel to the grain. They may be found in the sapwood just beneath the bark, deep in the sapwood, or in the pith. Where numerous, they may honeycomb the wood.

Hypothenemus rotundicollis (Eichhoff) occurs in the Southeastern States and breeds in the limbs of oaks and hickories. The adult is dark brown to black and about 1.6 to 1.8 mm long. *H. quercus* (Hopkins) attacks various oaks, hophornbeam, honeylocust, and hickories in the Southeastern States. The adult is dark brown and from 1.5 to 1.9 mm long. *H. chapuisi* (Eichhoff) breeds in sassafras and redbud. It has been recorded from Texas, Mississippi, Georgia, and North Carolina. The adult is dark brown to black and about 1.9 mm long. *H. interstitialis* (Hopkins) attacks oaks, hickory, walnut, and many other hardwoods. It has been recorded from Connecticut and Kansas to Florida. The adult is dark brown to black and from 0.9 to 1.6 mm long. There is a slightly reddish rugose area on the pronotum. The adult is dark brown and from 1.1 to 1.6 mm long. *H. obscurus* (F.) is frequently intercepted in shipments of Brazil nuts. *H. eruditus* Westwood attacks dogwood, redbud, hickory, and black cherry from Michigan and New Jersey south to Argentina. The adult is dark brown to black and from 1.1 to 1.3 mm long.

Ambrosia Beetles
Xylomycetophagus Scolytidae

Numerous species of beetles in the families Scolytidae and Platypodidae are known as ambrosia beetles because, in all cases, both the adults and larvae feed on a mold-type of fungus known as "ambrosia." The beetles introduce this fungus into tunnels bored into the sapwood and sometimes heartwood of trees and logs, where it grows on the walls and is propagated. Female ambrosia beetles possess specialized structures called mycetangia *(479)*, which are variously located in and on the body of the insect. In a few species these organs are found in the male and, in at least one species, *Xyloterinus politus* (Say), in both sexes *(2)*. Since the discovery that these specialized organs are possessed by ambrosia beetles, much important knowledge about the relationship of beetles to their specific microsymbiotic complexes has been gained *(41, 67, 392, 393, 441)*.

More than 54 genera of ambrosia beetles, some of which include up to 1,200 species, have been recorded throughout the world. A number of species breed in living trees, but decadent, dying, or recently cut trees, logs, and pulpwood or stumps are usually preferred. All species require a considerable amount of moisture for development. In the Southern States, timber is not attacked unless the moisture content of the wood is at least 48 percent. Seasoned timber is never infested *(205)*.

Ambrosia beetles are important chiefly because of the degrade of sawed lumber that results from their invasion of trees or logs. This degrade is caused both by holes bored into the wood and by the presence of black stains caused by the fungus inhabiting the tunnels. Trees cut during the summer in the South and left for more than 2 weeks in the woods are often severely damaged. This is especially true of sweetgum, baldcypress, and oak logs.

There are four general types of ambrosia beetle tunnels: simple, branched, compound, and cave. Simple tunnels are unbranched, often penetrating deeply into the wood. Branched tunnels penetrate deeply into the wood and then break up into several branches that extend in various directions on the same plane. Compound tunnels also branch off from a single entrance gallery but have egg niches extending upward and downward from the tunnel. In the cave-type gallery, a simple tunnel extends into the wood where it is expanded vertically upward and downward into a cavelike chamber in which the eggs are laid. One of the most common is the cave-type cavity made by *Xyleborinus saxeseni*. As these tunnels are excavated, the

beetles push the boring dust to the outside. The larvae of certain species live and feed in the egg niches which they expand into so-called cradles that branch off from the main galleries. Others live in the main galleries. The larvae of some species extend the galleries and cradles made by the parent beetles. Ambrosia beetle galleries differ from those of other wood-boring insects in that they are of uniform diameter throughout, are free of borings or other refuse, and have their walls stained black or brown.

Ambrosia beetles are discussed at greater length in several publications *(67, 76, 201, 421, 422, 619, 800, 1232, 1356)*.

The **Columbian timber beetle**, *Corthylus columbianus* Hopkins, occurs from Kansas to Massachusetts south to Florida and Arkansas. It breeds in various living deciduous trees such as sugar, silver, and red maples, sycamore, yellow-poplar, boxelder, basswood, beech, elm, yellow birch, and several species of oaks. Adults are robust, very dark brown to black, and about 3.6 to 3.8 mm long (fig. 171A). The front of the head of the female is broadly concave and covered with short, stiff hairs. That of the male is convex and almost hairless. The pronotum is broadly rounded and asperate in front. The elytra are shiny, striate, and coarsely and shallowly punctured. The declivity is armed with small tubercles.

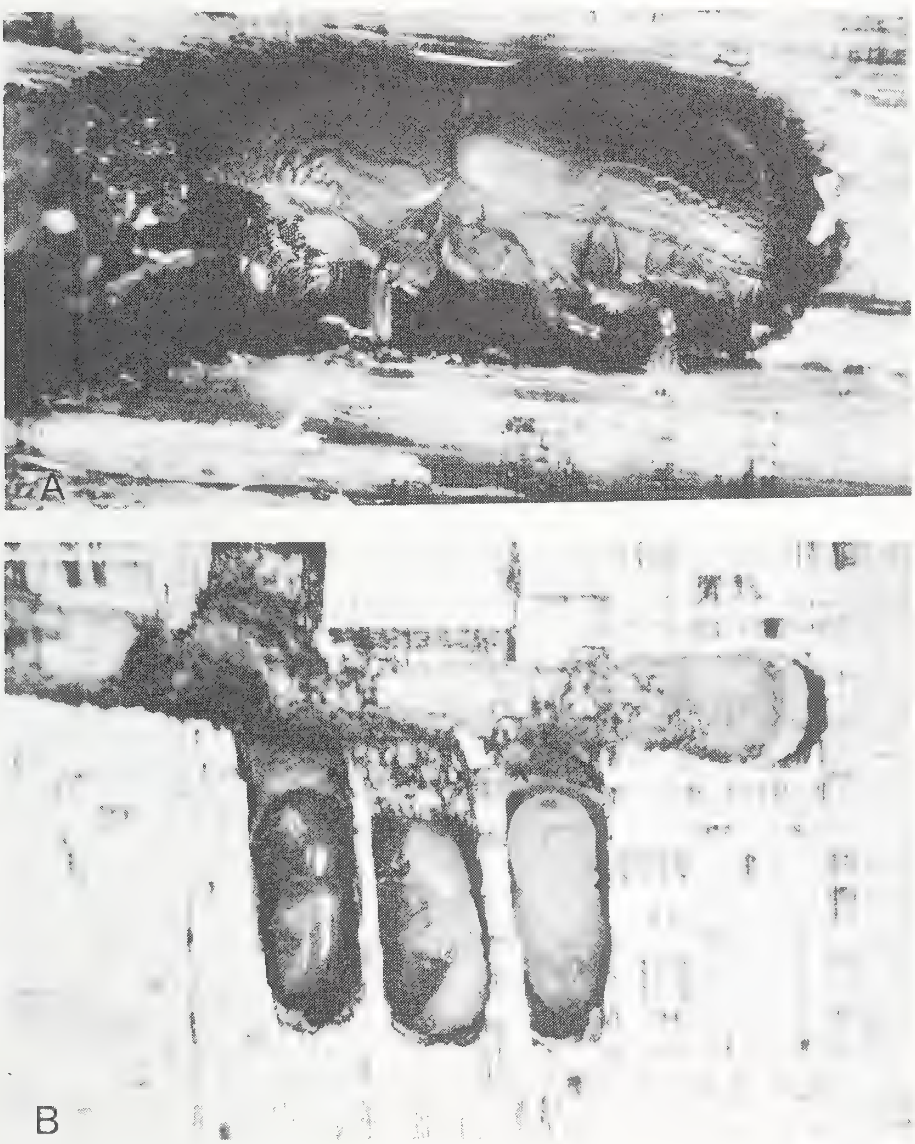


Figure 171.—The Columbian timber beetle, *Corthylus columbianus*: A, adult; B, callow adults in tunnels in the wood of a living red maple.

Adults become active during May and June in Indiana and West Virginia *(648)*. They tend to reattack the tree in which they develop, but some dispersal occurs *(933)*. The wood is entered through bark crevices, usually on the main trunk near the base. In oak, a tunnel is bored straight into the sapwood until it nears the heartwood, then it turns right or left (fig. 171B), whereas in diffuse porous wood such as maple and yellow-poplar, the tunnel branches but then extends toward the pith. Entrance holes are clean-cut and about 2 mm in diameter, with boring dust and sap exuding from them. Short tunnels or chambers leading from the upper and lower surfaces of the main tunnels are excavated at intervals. Eggs are laid in the chambers and the larvae live and develop in them. The larval food is a yeast of the genus *Pichia (649)* and another fungus, *Ambrosiella xylebori* Brader *(68)*. Food is stored and transmitted by prothoracic mycetangia possessed by the male beetle *(480)*. Winter is spent in the adult stage in short tunnels under bark scales or vines at the base of the tree *(932)*. There are two to three generations per year.

The Columbian timber beetle seems to prefer vigorous trees, and it attacks trees of practically all sizes. Damage is conspicuous in cross sections of the trunk of infested trees. Streaks of stain originating from the tunnels extend, often for considerable distances, above and below them. These and the black-stained tunnels cause defects known variously as "grease spots," "steamboats," "spot worm," "flag-worms," and "black holes." Damaged wood is rendered unfit for such uses as face veneer, cooperage, or furniture. In southern Indiana, red and silver maple woods, which are highly valued in the furniture industry, are reduced in value by 38 percent *(809)*.

Corthylus punctatissimus (Zimmermann), the **pitted ambrosia beetle**, occurs from southern Canada to Georgia and westward to Colorado. It breeds in a variety of trees and shrubs, such as maple, dogwood, American hornbeam, eastern hophornbeam, sassafras, rhododendron, and azalea. Young sugar maples are especially subject to damage, and destructive infestations in them have been reported both in North Carolina and southern Canada. Cultivated rhododendrons and azaleas are also frequently attacked and killed. The adult is rather stout, cylindrical, dark brown or black, and 3.0 to 3.3 mm long. The antennae and legs are rusty red-brown. The prothorax is longer than wide, roughly tuberculate in front, finely and sparsely punctured, shiny behind, and extends hoodlike over the head. The elytra are strongly punctured but not in rows, are rounded behind, and are without furrows or teeth.

The adult bores into its host near the ground line, then excavates a tunnel which may encircle the stem one or more times, girdling it. Small stems, from 3 to 12 mm in diameter, are usually attacked. Nearly all attacked stems die and annual mortality of 8 percent has been recorded in southeastern Canada *(419)*.

Two species of the genus *Monarthrum*, *M. fasciatum* (Say) and *M. mali* (Fitch), occur in eastern North America. Adults of *M. fasciatum* are yellowish brown with the anterior half of the prothorax and the posterior third of the elytra usually dark brown, and are about 2.3 to 2.8 mm long. In this species, mycetangia are possessed by the female *(753)*. This species is most common in the South but occurs as far north as Massachusetts and Wisconsin. It breeds in many species of hardwoods, and has also been observed in pine. Adults of *M. mali* resemble those of *M. fasciatum* except for their slightly smaller size and their uniform yellowish to light reddish-brown color. This species breeds in injured and dying trees or recently cut logs and stumps of many species of hardwoods throughout the Eastern States. The galleries of both species of *Monarthrum* are branched with larval chambers extend-

ing upward and downward from the tunnels *(201)*. Both species are highly destructive of green lumber and fresh logs of gum in the Gulf States.

Xyloterinus politus (Say), a widely distributed species in eastern North America, breeds in injured, dying, and recently cut trees and limbs of a variety of trees such as beech, birch, hard and soft maples, hickory, oak, ash, magnolia, black cherry, red spruce, pine, and hemlock. It is rare in coniferous hosts. The adult is dark brown to black and about 2.7 to 3.7 mm long. The pronotum is almost square, rugose in front, and has the anterior margin armed with four teeth. The galleries of this species differ from those of many other ambrosia beetles in that they often fork and branch secondarily, and they also possess four rows of larval cradles, two above and two below the gallery *(800, 801)*. Lumber cut from infested wood may be severely degraded by adult entrance holes and by associated stains.

Five species of the genus *Trypodendron* occur in eastern North America. Adults are distinguished by having completely divided eyes and by the absence of distinct sutures in the antennal club. The frons of the male is broadly excavated; that of the female is convex. The oral region of the head is visible from above. The gallery penetrates the sapwood and branches one or more times. The larvae are reared in cradles extending upward and downward from the tunnels. The cradles are enlarged by the larvae and serve as pupation chambers *(1356)*.

The **striped ambrosia beetle**, *T. lineatum* (Olivier), occurs over much of Canada, and the Western and Northeastern United States. It also occurs in the mountains of western North Carolina. It breeds in a wide variety of conifers and occurs rarely in hardwoods. The adult is from 2.7 to 3.5 mm long. They are dark brown to black, with each elytron usually marked with two light yellowish-brown stripes parallel to the suture. These stripes extend to the base of the pronotum. The main gallery of the species extends straight into the wood for 2.5 to 5 cm and then divides into two or more branches. Larval cradles are situated at the upper and lower surfaces of these branches. Damage to felled timber, and to damaged, injured, or fire-scorched trees is often severe.

Trypodendron scabricollis (LeConte) occurs from Minnesota and Arkansas eastward, and breeds in various species of pine and hemlock. The trunks (fig. 172) and larger limbs of weakened and dying pines are preferred, but freshly cut lumber is also subject to attack and serious damage. Adults are from 3.5 to 4.1 mm long, and brown with a faint, light stripe extending from the basal one-fourth of the pronotum down each elytron. The elytra are smooth and finely striate. The gallery system has an entrance tunnel extending 2.5 to 5.0 cm into the wood. The gallery branches left and right, following an annual ring. Larval cradles extend above and below these secondary tunnels *(76)*.

Trypodendron retusum (LeConte), the largest of the eastern species, attacks poplars across the Northern United States and southern Canada. It has also been recorded from West Virginia and several Western States from Alaska to Arizona. Adults are 3.6 to 4.6 mm long and uniformly black when fully mature except for pale yellowish-brown areas at the base of the pronotum and on the elytra from the base to the declivital margin continuing on the sides of the declivity to the apex. *T. betulae* Swaine occurs throughout the Northern States and across Canada, and breeds in unthrifty standing birch. Adults are dark brown to black and from 2.7 to 3.5 mm long. There is a faint yellowish-brown area of variable size on each elytron from the base to the declivital margin *(1356)*.

Trypodendron rufitarsis (Kirby) attacks injured or dying pines and spruces, evidently preferring standing trees over logs. It occurs over much of western North

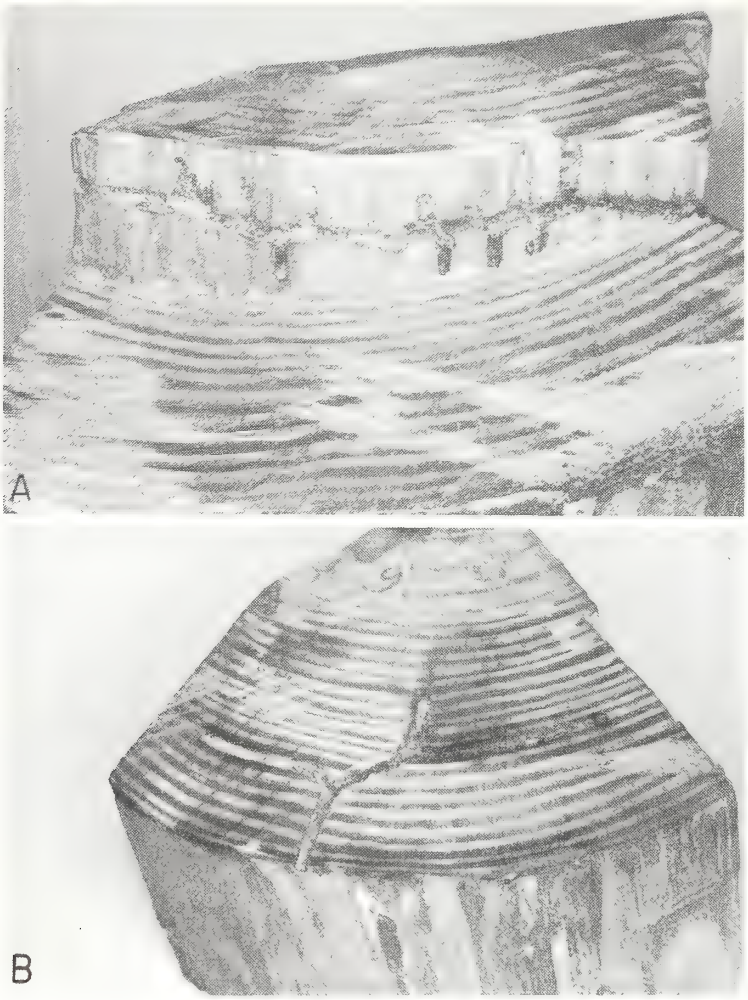


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Figure 172.—Two examples of damage from tunnels of the ambrosia beetle, *Trypodendron scabricollis*, in loblolly pine.

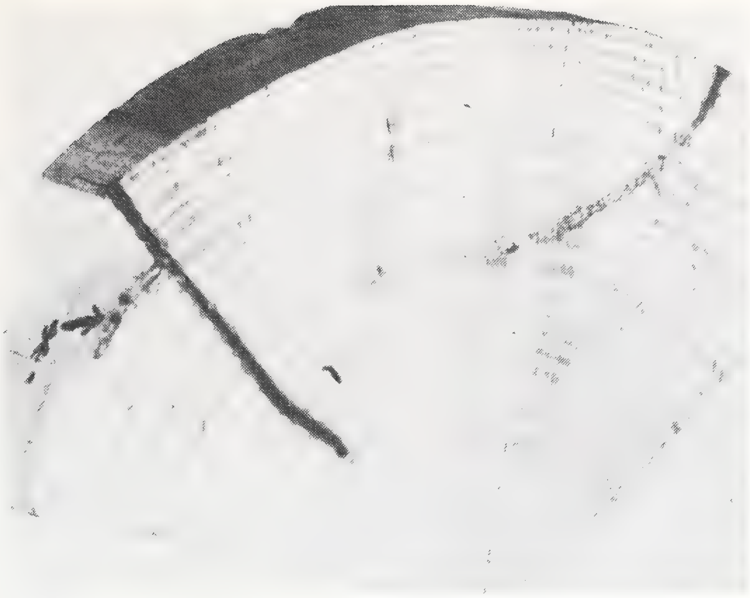
America but it has been found in northern Minnesota and eastern Canada *(1356)*.

The genus *Gnathotrichus* contains several species of true ambrosia beetles *(117)*. The adults are small, cylindrical, and dark brown or black. The head is invisible from above, and the body surface is finely punctured, smooth, and sparsely covered with hairs near the elytral declivity.

Gnathotrichus materiarius (Fitch) occurs from eastern Canada south to Florida and westward to South Dakota and eastern Texas. It breeds in the lower portions of the trunks of dead and dying pines, spruce, balsam fir, larch, and perhaps other conifers. Adults are dark brown and about 1.7 to 3.1 mm long. The elytra are glabrous except for the declivity and sides which have short, sparse hairs. The declivity of the elytra is grooved at the suture.

Adults bore directly into the wood and their main galleries may have several branches (fig. 173). Larval cradles are extended both upward and downward from these galleries, and run parallel to the grain of the wood. Pines killed by *Ips* bark beetles in the South are often attacked by this species *(76)*.

The genus *Xyleborus* is represented by 19 native and introduced species in the Eastern United States *(152, 1356)*. All species are ambrosia beetles. Many breed in both conifers and deciduous trees and shrubs of all sizes. Dying, unhealthy, felled, or weakened trees or wounds and dead areas in living trees are preferred for attack. Males are very rare, quite different from females, and flightless.



Courtesy Duke Univ. Sch. For.

Figure 173.—Tunnels of the ambrosia beetle, *Gnathotrichus materiarius,* in the wood of a shortleaf pine.

Xyleborus celsus Eichhoff, the largest member of the genus occurring in the United States, breeds in dead, dying, and recently felled trees and stumps of hickory in the Eastern United States west to Iowa and Texas. Females are reddish brown and about 3.6 to 4.5 mm long. The declivity of the female is steep, almost flat. The sides and upper margin of the declivity are armed with several acute tubercles, and the area between the suture and first stria is broad, smooth, and armed with two large teeth. The galleries of this species extend directly into the wood for 1 to 3 cm or more, then branch one to six times in a fan shape. Eggs are laid near the ends of the galleries. There are two generations per year in southern Missouri *(459)*. Hickories killed by the hickory bark beetle are especially subject to attack in the Southeast *(76)*.

Xyleborus dispar (F.) is widely distributed in southern Canada and the Eastern States south to North Carolina. It attacks all the common fruit trees as well as a great many other hardwood trees. It has also been reported from pine and hemlock. Females are black and 2.8 to 3.5 mm long. In large trunks, the galleries extend straight into the wood from 1 to 3 cm and branch on the same plane following an annual ring. In small trunks and branches, the galleries spiral upward from the point of attack around the stem or limb, branching upward or downward from the spiral gallery *(201)*.

Xyleborus ferrugineus (F.) occurs from Massachusetts and Michigan south to Florida and Texas. It breeds in dead, dying, or felled trees of a wide range of species including oak, hickory, ash, baldcypress, walnut, pine, beech, and sweetgum. Females are reddish brown and from 2 to 3.3 mm long. The elytral declivity of the female is flat. The third interspace of the declivity is armed with one to three acute granules on the basal half and one coarse denticle at the middle; the fourth and fifth interspaces are armed with two to four granules each. Galleries resemble those formed by *X. celsus* except that they are smaller in diameter; they also may be longer and more winding and branch less frequently in the same plane. Side branches are formed which lead to other sets of galleries at different levels. The galleries may penetrate all of the sapwood but they are less common in the heartwood. *X. ferrugineus* may form shallow galleries that are visible on the surface of the wood when the bark is peeled *(1356)*.

Xyleborus affinis Eichhoff occurs in the Eastern United States east of a line from Missouri to Texas and south of Michigan and Massachusetts. It breeds in dying trees and in green logs and lumber of various hardwood trees such as oak, hickory, sweetgum, river birch, hackberry, silktree, persimmon, baldcypress, and black locust. Adults are yellowish to reddish brown and are from 2.0 to 2.7 mm long. The elytral declivity of the female is dull, opaque, and broadly sloping, and the interspaces are armed with a few minute granules. Galleries are similar to those of *X. ferrugineus* except surface galleries are more commonly found and usually more extensive. Adjacent tunnels are often interconnected, and there are no cradles *(76, 1356)*.

Other eastern members of the genus and their hosts are as follows: *X. xylographus* (Say)—oaks; *X. pubescens* Zimmermann—pines; *X. intrusus* Blandford—pines; *X. obliquus* (LeConte)—birch, hickory, and chestnut; *X. rubricollis* Eichhoff—oak, hickory, walnut, dogwood; *X. lecontei* (Hopkins)—hickory and palm in Florida; *X. tachygraphus* Zimmermann, *X. obesus* LeConte (the **stout ambrosia beetle**), and *X. sayi* (Hopkins)—a wide variety of deciduous trees; *X. volvulus* (F.)—probably various deciduous trees and shrubs in southern Florida; *X. devexulus* Wood—hickory; *X. validus* Eichhoff—beech and black oak; and *X. planicollis* Zimmermann, *X. viduus* Eichhoff, and *X. opimus* Wood—for which the hosts are unknown.

Xyleborinus saxeseni (Ratzeburg) occurs commonly throughout southern Canada and the United States and breeds in a wide variety of trees. Some of its more important eastern hosts are pecan, hickory, honeylocust, walnut, sweetgum, yellow-poplar, oak, American beech, maple, birch, dogwood, persimmon, holly, hemlock, baldcypress, and shortleaf and loblolly pines. The adult is dark brown and from 1.6 to 2.4 mm long. It is distinguished from *Xyleborus* spp. by its conical scutellum. The elytral declivity of the female is steep, convex, shallowly bisulcate, and armed with two rows of five to seven acute tubercles on each side of the suture. The male is smaller with all characters poorly formed. The gallery of this species consists of a single tunnel bored 1 to 7 cm directly into the wood. The innermost section of the tunnel is widened vertically upward and downward into a cavelike chamber in which eggs are laid and in which the larvae live and feed. The larvae feed on ambrosial fungi and wood, enlarging the tabular tunnel of the female. The life cycle is completed in 2 months. This species can cause severe economic damage *(1356)*.

The genus *Xylosandrus* is represented in the United States by five species, of which at least four are introduced. They usually breed in twigs, branches, and small stems of trees and other plants *(1356)*. The female excavates a tunnel into the pith of small stems or into the wood for 1 to 3 cm. Here a small cavity is made where the eggs are laid. The larvae feed on ambrosial fungi growing on the walls of the tunnel and also apparently on the host tissue as they enlarge the gallery.

Xylosandrus zimmermanni (Hopkins) has been recorded in southern Florida, Mexico, and northern South America. Its hosts are listed as red maple and ardisia species. *X. germanus* (Blandford) breeds in the branches, logs, and stumps of a wide variety of hosts including maple, oak, hickory, beech, dogwood, elm, ash, other hardwoods, and pine. It occurs from Connecticut and New Jersey west to Illinois and Kentucky. Heavy infestations have been found in elms killed by the Dutch elm disease. It is capable of transmitting Dutch elm disease fungus to healthy trees *(167)*. It has also been found associated with *Fusarium* cankers on yellow-poplar and black walnut *(22)*.

The **black twig borer**, *X. compactus* (Eichhoff), introduced from southeast Asia, was first detected in Florida and Cuba in 1941. It has invaded Georgia, Mississippi, and Louisiana, and will probably spread throughout much of the Southeastern United States. Vigorous terminal twigs of more than 200 known host species are attacked and killed. Hosts include maples, hickories, magnolias, oaks, willows, and many others. This aggressive species is a serious pest in deciduous forests and in horticultural areas. In Florida, smaller twigs (1 to 7 mm in diameter) of dogwood were infested by single females, and larger twigs contained several females *(927)*.

Xylosandrus morigerus (Blandford), the **red shothole borer**, was introduced from southeast Asia, and has spread from Mexico to Brazil. It has been intercepted at several ports of entry in the United States but it has not yet become established. It breeds in broken or cut branches about 1 to 3 cm in diameter *(1356)*.

Xylosandrus crassiusculus (Motschulsky), also from southeast Asia, was found near Charleston, S.C., in 1975 on cherry. Its galleries resemble those of *Xyleborus dispar* (F.) *(1356)*.

Family Platypodidae
Platypodid Beetles

Almost all members of this family are ambrosia beetles and they occur principally in the tropics and subtropics. Only one genus has been recorded from the United States *(1355)*. The adults differ from those of other ambrosia beetles in having longer and more slender bodies and wide heads flattened in front, not covered by the pronotum. The first segment of the tarsus is as long as the other three tarsal segments combined, and there are spinelike projections at the seam of the elytra of the males *(201)*.

Members of the family are usually more destructive than other ambrosia beetles. Their tunnels are more extensive, and they extend deeper (25 to 30 cm) into the sapwood and heartwood. Dying, weakened, or recently felled trees are usually preferred; however, vigorous, healthy trees are also attacked if dead areas of bark are present. Eggs are laid in small loose clusters in the tunnels. Larvae and adults are also found in these tunnels.

Platypus flavicornis (F.) occurs in the Eastern United States from New Jersey to Florida and west to Texas and Mexico. It breeds commonly in various species of pines and occasionally in several species of hardwoods. Dead and dying trees, stumps, and logs cut or left in the woods during the summer are preferred. It is commonly found in the lower 1 m of trees killed by southern pine beetle *(245)*. Adults are reddish brown and about 5 mm long. The front of the head is flat and clothed with moderately long hairs; the pronotum is longer than broad and densely but shallowly punctured; and the elytra are elongate and striate, with the third, fifth, seventh, and ninth interspaces produced into blunt, toothlike processes on the declivity of the male. The adult bores a horizontal gallery in the sapwood (fig. 174). Here, it may branch extensively and extend into the heartwood. The lower portions of infested trees are sometimes literally riddled. In the South, this species is so abundant that very few dying pines, stumps, or logs escape attack. Large amounts of white downy frass is evidence of attack *(76)*.

Platypus quadridentatus (Olivier) occurs throughout the South from Florida to Texas and north to West Virginia. Various species of hardwoods, especially the oaks, are most commonly attacked. Adults are dark reddish brown and about 4.5 mm long. The front of the head is shallowly and densely punctured and sparsely clothed with moderately long hairs. The pronotum is longer than broad, and in the

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Figure 174.—Egg cradles of the ambrosia beetle, *Platypus flavicornis*.

female, it bears two large pits just behind the middle. The third, fifth, and seventh interspaces of the elytra are produced into toothlike processes on the elytral declivity of the male. Two large tuberosities also occur on the lower edge of the declivity in the male, and two hooklike spines are on the fourth abdominal segment *(76)*.

Platypus compositus (Say) occurs throughout the Southern States northward to southern New York and southern Illinois. It breeds in a wide variety of deciduous trees such as hickory, pecan, birch, poplar, oak, chestnut, basswood, elm, beech, sweetgum, tupelo, magnolia, baldcypress, and persimmon (fig. 175). Recently felled or girdled baldcypress is often seriously damaged. Adults are light reddish-brown and about 4.5 mm long. The front of the head is densely punctured above, and there are two centrally located pits just behind the middle of the pronotum. The first, third, fifth, and seventh interspaces of the elytra of the male are produced into small tubercles on the declivity. The declivity of the male also bears two large tridentate teeth at the outer apical angle *(76)*.

Courtesy Duke Univ. Sch. For.

Figure 175.—Tunnels and larval cradles of the ambrosia beetle, *Platypus compositus*, in the wood of persimmon.

Platypus parallelus (F.) apparently is the most destructive ambrosia beetle in the world. Although it occurs in Florida, Texas, and southern California, the unfavorable climate prevents this tropical species from becoming sufficiently abundant to cause more than minor damage to hardwood trees in North America.

Ambrosia beetle control is largely a matter of preventing damage to recently cut logs through quick removal from the woods, proper storage of logs at the mill, and by proper handling of lumber and milled products *(76)*.

Order Hymenoptera—*Ants, Bees, Sawflies, Wasps, and Allies*

The order Hymenoptera is one of the largest orders of insects, with more than 20,000 species in America north of Mexico. Most are beneficial and many are very important to forestry and agriculture either as parasites or predators of pests or as pollinators of more than 100 commercially grown crops. The honey bee is one important pollinator. Among the relatively few injurious Hymenoptera are the sawflies, some of which are stem borers attacking crops or serious defoliators of coniferous trees *(697)*.

The winged members of the order characteristically have four membranous wings, the front pair larger and more completely veined than the hind pair. The hindwings have a row of tiny hooks along the anterior margin by which they are attached to the forewings. Some forms, or groups, such as workers of the common ant, are wingless. The ovipositor is usually well developed and in the higher forms is modified into a sting.

The order is divided into two suborders—Apocrita (= Clistogastra) and Symphyta (= Chalastogastra) *(697)*. Each of these, in turn, is divided into a number of superfamilies.

Suborder Symphyta (= Chalastogastra)

Members of the suborder Symphyta are distinguished by having the abdomen of the adult broadly joined to the thorax—the second abdominal segment is not constricted into a petiole as in the suborder Apocrita. The ovipositor of the female is well developed and fitted for making incisions in the leaves or stems of plants. In the majority of species it is sawlike. Because of this, these members of the suborder are known as sawflies.

The larvae of all species, except for the family Orussidae, are phytophagous, the majority feeding externally on the foliage. The remainder bore into stems, fruit, wood, or leaves, and some form galls. Orussid larvae are parasitic on wood-boring coleopterous larvae. While externally leaf-feeding larvae look like lepidopterous larvae, they have only one simple eye on each side of the head and have six or more pairs of prolegs on the abdomen, none of which bears hooks or "crochets."

The suborder Symphyta is represented in the United States and Canada by more than 1,000 species, many of which are highly destructive of forest and shade trees and of young trees in nurseries and plantations.

Superfamily Megalodontoidea—Family Xyelidae
Xyelids

Members of the family Xyelidae are medium-size to small sawflies, mostly less than 19 mm long. They differ from all other sawflies in having the third antennal segment elongate with a slender terminal filament of 9 to 25 segments, and in having three marginal cells in the forewing. Unlike all other sawflies except the Pamphiliidae, they have the costal cell divided by a longitudinal vein.

The genus *Xyela* contains several species that feed as larvae on the developing pollen of the male strobili of various species of pines and one species forms shoot galls on several species of pines. The adults are often found feeding on pollen of catkins of willow, alder, and other trees in flower during the adult flight period, and occasionally on the pollen of pines. Only 17 species are known in North America, of which 7 are found in eastern pine forests. *X. bakeri* Konow, reared or collected from longleaf, slash, jack, Virginia, and shortleaf pines, is known to occur from Quebec to Florida, westward to British Columbia, and California. *X. minor* Norton, whose known hosts include Virginia, slash, loblolly, and longleaf pines, ranges from Quebec to Florida, westward to British Columbia, and California. *X. obscura* (Strobl), reared or collected from Virginia, jack, slash, longleaf, and loblolly pines, is known from Newfoundland to Florida westward to California, Northwest Territories, British Columbia. *X. dodgei* Greenbaum, collected beneath sand pine, is known only from Cedar Key, Fla. *X. alpigena* (Strobl), whose known hosts are white pines, ranges from Quebec, Maine, to Maryland, westward to Utah, New Mexico. *X. styrax* Burdick, collected from Virginia pine is known from New York, Maryland, Virginia, and Georgia. *X. gallicaulis* Smith, the **pine shoot gall sawfly**, is collected and reared from spindle-shaped galls on new shoots of loblolly, shortleaf, and slash pines in Virginia and Georgia (fig. 176). Adults emerge in December and oviposit presumably in the dormant buds of host trees. Egg hatch is timed with bud elongation, and the larvae form a gall. Full-grown larvae drop to the soil where prepupae form cocoons. Adults emerge 19 months later. The curculionid, *Conotrachelus caroliniensis* Schoof, feeds externally on sawfly galls, which damages weakened shoots and causes them to break in the wind. Xyelid sawflies occurring on slash and longleaf pines in Florida are discussed in the literature *(358, 547)*.

Pleroneura brunneicornis Rohwer is recorded from balsam and white firs from eastern Canada and from Maine and New York to Minnesota *(1103)*. Mature larvae are white, measuring 4 to 7 mm long. The thoracic legs are weakly developed and prolegs are reduced to slight swellings. In New Brunswick, Canada, adults fly during late May. Eggs are deposited within tightly packed needle clusters on expanding buds, and larvae feed in tunnels excavated in the center of new shoots. Mined shoots die and turn reddish brown, an effect similar to that caused by late frost. Mature larvae drop to the ground and overwinter in thin, oval cocoons spun within an earthen cell. There is one generation per year *(1260)*.

Several species of *Megaxyela* have been observed feeding as larvae on hickory and walnut, and *M. langstoni* Ross has been reared from pecan. *Macroxyela ferruginea* (Say) has been recorded as feeding on elm.

Family Pamphiliidae
Webspinning Sawflies

The family Pamphiliidae is represented in North America by 4 genera and 72 or more species, of which more than half occur in eastern America. The adults are moderately large with long, many-segmented antennae. The abdomen is flattened and has sharp lateral margins; the ovipositor of the female is short. Larvae have the venter flattened and are about 15 to 25 mm long. The thoracic legs are well developed, abdominal legs are absent, and the last abdominal segment bears a pair of three-segmented subanal appendages. The larvae of certain species are gregarious and feed together in nests that they prepare by webbing together leaves of their hosts. Others roll the edges of leaves or spin silken tubes in which to live *(845)*.

The **pine false webworm**, *Acantholyda erythrocephala* (L.), an introduced

species first recorded in Pennsylvania in 1925, now occurs in Connecticut, New Jersey, Pennsylvania, and Ontario. Its preferred hosts are eastern white and red pines, but it also attacks several other pines, including Scotch, Austrian, Swiss mountain, and Japanese red. Female adults have orange-red heads and steel-blue bodies; males are almost entirely steel-blue. Full-grown larvae are pale greenish-gray and about 16 to 20 mm long. The head is clay yellow with dense, small dark-brown spots, and there are longitudinal stripes of purplish red on the dorsum, venter, and sides. The prepupa is bright apple-green.

Winter is spent in the prepupal stage, pupation occurs in early spring, and adults appear from about mid-April to mid-May. Eggs, in short rows of 3 to 10 each, are deposited over small slits cut into the previous year's needles. The larvae spin loose webbing about themselves and feed gregariously on the old needles. Young larvae cut the needles off just above the bundle sheaths and pull them into the webbing, where they are consumed. Older larvae feed singly from within individual silken tubes spun around themselves along twigs. Considerable amounts of frass and bits of needles usually adhere to the exterior of these tubes *(1333)* (fig. 177). Full-grown larvae drop to and enter the ground for hibernation in an earthern cell. There is one generation per year. Heavy infestations sometimes develop locally, causing severe defoliation *(505)*.

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Figure 176.—Pine shoot gall sawfly, *Xyela gallicaulis*, on new shoot of loblolly pine in Georgia.

Courtesy Conn. Agric. Exp. Stn.

Figure 177.—Damage and webbing by the pine false webworm, *Acantholyda erythrocephala*.

Acantholyda zappei (Rohwer), the **nesting-pine sawfly**, occurs from Quebec to New Jersey west to Michigan. Its hosts are various species of pines such as red, jack, Austrian, pitch, and Japanese red. A full-grown larva is green, with a brown head and a dark-green dorsal stripe, and is about 18 to 25 mm long. Eggs are laid singly on young needles of the current year's growth from late June to early July. Young larvae spin webs about themselves and fasten the outer threads to the needles. Needles are cut off near the base and drawn into the web where they are consumed. Webs are increased in size as the larvae develop, and may reach a length of 13 cm by the time the larvae are full grown. Winter is spent as prepupae in cells in the soil, and pupation occurs in the spring. There is one generation per year *(1370)*.

Acantholyda circumcincta (Klug) has been recorded from New Brunswick, Quebec, Pennsylvania, Georgia, and Florida. During May and June 1968, it severely defoliated approximately 40 hectares of sand pine in west Florida. Known details of its life history are similar to those of *A. erythrocephala (203)*.

Some additional eastern species of *Acantholyda*, along with known hosts and known areas of distribution, include the following: *A. apicalis* Westwood—loblolly pine in North Carolina, Georgia, Florida, Mississippi, Arkansas; *A. pini* Rohwer—red pine in Quebec, Ontario, Michigan, south to Georgia; *A. angulata* (MacGillivray)—eastern white, pitch, jack, Austrian, and Japanese red pines in New Brunswick, Quebec, south to North Carolina, west to Minnesota; *A. luteomaculata* (Cresson)—white and jack pines, preferably eastern white, from New Brunswick to Connecticut, west to Ohio, Minnesota; *A. floridana* Greenbaum—slash and sand pines in Florida; *A. maculiventris* (Norton)—firs and white spruce from Labrador to North Carolina, west to British Columbia, Wyoming, California.

Cephalcia fascipennis (Cresson) occurs in Quebec, Nova Scotia, New Hampshire, west to British Columbia. Its hosts are listed as blue and white spruces. Full-grown larvae have a black head and thorax, and a green body. They are about 25 mm long. Ornamental spruce and hedges are sometimes rendered unsightly by the presence of larval nests *(375)*. *C. fulviceps* (Rohwer) feeds on jack and red pines in southern Canada, New Hampshire, Connecticut, and New Jersey. *C. marginata* Middlekauff feeds on young red pines in Nova Scotia, Quebec, New York, Massachusetts, Connecticut, Pennsylvania, Virginia, and West Virginia. Its life history is discussed *(277)*.

Pamphilius phyllisae Middlekauff is widely distributed in Eastern United States and Canada *(376)*. Only one outbreak has been recorded for *P. phyllisae*, and it occurred in Pennsylvania following a period of several droughty years. At this time the host severely impeded parasitism by encapsulating nearly all of the parasites *(376)*. The life cycle may require 1 or more years, with about 6 weeks spent as feeding larvae.

The **plum webspinning sawfly**, *Neurotoma inconspicua* (Norton), occurs in Quebec, Massachusetts to Pennsylvania, west to British Columbia, Montana, and Kansas. Its hosts are listed as hawthorn and various wild plums and wild cherries. The adults are black with supraocular spots, their wings are hyaline with faint bands beneath the stigma, and their legs are mostly reddish brown beyond the coxae. The larvae are gregarious; they web the foliage together to make webs somewhat similar to those of the fall webworm. Heavily infested trees no more than 1.8 m tall may support up to 25 webs, some of which may enclose entire branches. Such trees may be completely defoliated.

Neurotoma fasciata (Norton), the **cherry webspinning sawfly**, occurs from Quebec to Florida, west to Wisconsin, Missouri, and Arkansas. Its hosts are listed as black and pin cherries. The full-grown larva has a shiny black head and prothoracic plates, and a deep green body; it is about 18 mm long. The larvae are gregarious and construct dirty-brown nests on branches and shoots, especially on young trees. Prepupae overwinter in cells in the soil and some of these pupate in the spring. The remainder do not pupate until late fall or the following spring. The related species, *N. crataegi* Middlekauff, feeds on hawthorn from Massachusetts and New York, west to Manitoba, Wisconsin, and Illinois.

Superfamily Tenthredinoidea
Sawflies

Members of the superfamily Tenthredinoidea are commonly called sawflies because of the sawlike ovipositor of the female. The ovipositor is composed of three main pieces held within protecting sheaths. The upper piece is rigid and consists of a pair of fused lances, with ventral grooves along which the other two pieces slide. These last two are called the lancets, or saws. They consist of thin plates with their flat inner surfaces together. Each plate is usually shaped like a long, acute triangle with the dorsal edge along a groove of the lance. The ventral edge is usually sawtoothed. The rod that attaches the blade to the abdomen and controls its movements originates at the narrow base of the lance.

Sawfly larvae resemble lepidopterous larvae but are usually naked. A few, however, are spined, hairy, or covered with a gummy or waxy secretion. The best single feature for distinguishing sawfly larvae from lepidopterous larvae is the presence of only one simple eye on each side of the head—lepidopterous larvae have six on each side. When disturbed, the larvae of certain sawfly species curl up and lie on their sides, whereas others hold their abdomens aloft over their heads or raise the head and thorax. The majority are external feeders on foliage, either eating entire leaves or skeletonizing them. Some feed from within; a few feed within mines in the leaves, leaf petioles, and twigs; some produce galls on the leaves or shoots; and a few feed on catkins, buds, or fruits. When they reach maturity they either spin cocoons or construct cells in which to pupate. Cocoons may be spun on leaves, twigs, or other parts of the host, or they may be spun in the litter or soil beneath the trees. Cells are formed in pith, bark, and brashy wood, or in the ground. Leafmining species sometimes form their cocoons within their mines.

Sawfly adults frequently resemble small bees or wasps, except for their antennae and the broad connection between thorax and abdomen. The antennae may be feathered, clubbed, threadlike, forked, or may bear spurs on some of the joints.

Sawflies constitute one of the most destructive groups of insect defoliators in eastern forests. Outbreaks occur frequently and sometimes spread over large areas and persist for several years before subsiding. Damage is often severe, especially in coniferous plantations. Outbreaks of an increasing number of species infesting pines have been reported during recent years, possibly as a result of the establishment of numerous pine stands in planting programs. Lists of the species in the superfamily occurring in America north of Mexico have been published *(697)*.

Family Pergidae
Pergid Sawflies

The family Pergidae is represented in Canada and the United States by only one genus, *Acordulecera*. Four species are now listed from the Eastern United States west to Arizona *(697)*. Full-grown larvae are usually greenish with light or blackish heads and distinct lateral lobes, and measure less than 12 mm long. Each body

segment bears transverse rows of slight tubercles armed with short, stiff setae. The larvae feed gregariously on the foliage of oak, butternut, hickory, hawthorn, and pecan, and occasionally are abundant enough to attract attention. Adults appear in May and June; larvae are present from June to August, and overwinter in cocoons in the ground. There is usually one generation per year, but some species occasionally have a partial second.

Family Argidae
Argid Sawflies

The family Argidae is represented by 8 genera and 59 species in the United States and Canada, the majority of which occur in the Southwestern United States *(697)*. The adults are medium- to small-size, stout-bodied sawflies. They can be recognized by their three-segmented antennae, the third segment of which is very long and bifurcate in males of some groups. The more common species are usually reddish brown or bluish black, with more or less dark-brown wings. Larvae are yellowish green or red and are usually spotted. The body is often rather thick-set, widest on abdominal segments one to three, tapering toward the rear end, and the venter is often flattened.

The **birch sawfly**, *Arge pectoralis* (Leach), is widely distributed in eastern North America. Its preferred hosts are various birches, especially gray and paper. It also has been recorded feeding on willow and alder. Full-grown larvae are about 18 mm long. The head is reddish yellow; the body yellowish, with six rows of black spots on top and three on each side. Adults appear during June and July and deposit their eggs in slits cut in the margins of leaves. Larvae are present from July to September, and winter is spent as prepupae in cocoons spun in the litter on the ground. The species is of no economic importance, although it occasionally becomes abundant enough to cause noticeable defoliation over limited areas.

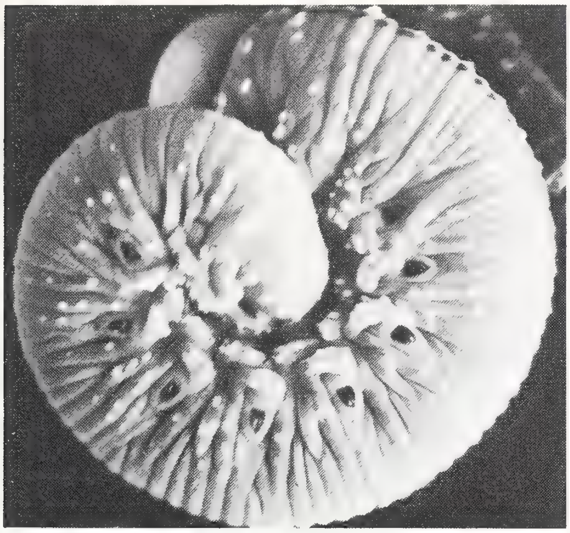
Additional species of argid sawflies likely to be encountered on trees and shrubs in the Eastern United States are: *A. clavicornis* (F.)—on willow, birch, hawthorn, plum, hornbeam, and azalea; *A. scapularis* (Klug)—on oak, alder, elm, and birch; *A. coccinea* (F.)—on sumac; *A. abdominalis* (Leach)—on birch and azalea; *A. humeralis* (Beauvois)—on poison-ivy and poison-sumac; and *Sterictiphora* spp.—on plum and cherry.

Family Cimbicidae
Cimbicid Sawflies

The family Cimbicidae is represented in the United States and Canada by 3 genera and 12 species, some of which have been recorded feeding on trees in the Eastern States *(697)*. The adults are large with clavate antennae. The tibiae are without preapical spurs; however, there are single apical spurs on the front tibiae. Full-grown larvae have large heads, and their bodies taper toward the rear, and they are sometimes covered with a waxy bloom.

The **elm sawfly**, *Cimbex americana* Leach, is the largest of the North American sawflies. It is widely distributed, occurring from coast to coast in southern Canada and throughout the United States. The larvae feed primarily on the foliage of elm and willow, but are also observed occasionally on basswood, birch, maple, poplar, and alder. The antennae of adults are tinged with orange; the head and thorax, black; the wings, smoky brown; and they are about 25 mm long. The female's abdomen is usually steel blue, with three or four yellowish spots on each side and a faint, whitish spot near the thorax. In the male, the whitish spot near the thorax is distinct, but there are no yellowish spots on the sides. Full-grown larvae are yellowish white or greenish white with a pebbly skin and a black dorsal stripe, and

about 43 mm long. While feeding, the larva usually coils its rear end around a stem or twig; at rest, it usually lies coiled like a snail (fig. 178).



Courtesy Conn. Agric. Exp. Stn.
Figure 178.—Larva of elm sawfly, *Cimbex americana*.

Adults appear from about mid-May to mid-August, and the eggs are deposited in pockets cut into leaf tissues. Larvae occur from June until October, depending on location. When they become full grown, they crawl to the ground and spin tough, papery cocoons in the litter or just below the surface of the soil. Winter is spent in the prepupal stage, and pupation occurs in the spring. There is one generation per year.

The elm sawfly is of minor importance as a defoliator of forest trees, but occasionally seriously defoliates shade tree elms. Willow also has been heavily attacked in the Northern Great Plains area. The larvae partially or entirely defoliate the trees, while the adults chew the thin, tender bark of twigs, girdling and killing them *(1152)*.

Trichiosoma triangulum Kirby occurs quite commonly in the Eastern United States. The larvae are solitary feeders on the foliage of ash, birch, poplar, willow, and wild cherry. At maturity, they are 37 mm long. The head is creamy white, the body greenish white, and the eye spots and spiracles blackish. The life cycle is similar to that of the elm sawfly.

Family Diprionidae
Conifer Sawflies

The family Diprionidae includes many of the most serious defoliators of conifers. The majority of species are native to the continent but several of foreign origin are well established. The family is divided into two subfamilies, Monocteninae and Diprioninae, and six genera *(1099)*. Adults are described as follows: Antennae composed of 13 or more segments, serrate in the female, and pectinate or bipectinate in the male. Mesosterno-pleural sutures atrophied, mesoscutellum with anterior margin V-shaped, posterior margin with an extremely narrow and cordlike postergite *(1041)*. The larvae usually range in length from about 18 to 25 mm. The body is usually whitish, yellowish, or grayish with brown or black stripes or rows of more or less distinctly separated spots *(1369)*.

Many species of diprionids are serious pests in both forest stands and plantations. Outbreaks occur periodically, sometimes over extensive areas, resulting in loss of growth and sometimes tree mortality *(29, 31, 238)*.

The genus *Monoctenus* is represented in the United States and Canada by three species, all of which occur in eastern North America on *Juniperus* spp., and *Thuja* spp. None is considered a serious pest of forest or shade trees. *M. suffusus* (Cresson) and *M. fulvus* (Norton) occur in southern Canada and in the Northeastern States west to Kansas. Their hosts are redcedar, northern white-cedar, and juniper. Full-grown larvae are dull green and about 18 mm long. The head is light brown; the body is marked with three, dark longitudinal stripes; and the legs are black. Adults appear in May, and larvae are active during June and July.

The genus *Neodiprion* contains more than 30 species in North America *(697)*. Many of the most destructive species of sawflies are in this genus. Outbreaks of several species have occurred, resulting in serious damage to young pines on thousands of hectares of pine plantations in the Eastern United States, and sometimes spreading over thousands of hectares of forested areas before subsiding. Several authors have discussed the taxonomy of the genus *(30, 1042)*. A list of world species and their distribution is available *(1099)*. Life cycle information, in addition to preserved specimens of reared adults and feeding larvae, is often needed for positive identification of *Neodiprion* sawflies *(697)*.

The **redheaded pine sawfly**, *N. lecontei* (Fitch), occurs in southeastern Canada and throughout the Eastern United States. Its preferred hosts are jack, red, shortleaf, loblolly, slash, longleaf, pitch, and Swiss mountain pines. Eastern white pine, larch, deodar cedar, and Norway spruce may also be defoliated, especially where they are growing close to trees of preferred species. Full-grown larvae are about 20 to 30 mm long. The head is reddish and the body is yellowish white, with six rows of black spots (fig. 179).

Pupation occurs in early spring and the adults appear in a few weeks. Eggs are deposited in the tissues of current or previous year's needles, a single female depositing up to 150 eggs. The larvae feed gregariously on new and old needles and also on the tender bark of young twigs. Sometimes they completely defoliate a tree, progressing from the top downward, before they reach maturity. When this happens, larvae may abandon the tree and migrate for distances of several meters in

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Figure 179.—Larvae of the redheaded pine sawfly, *Neodiprion lecontei*, on loblolly pine.

search of new foliage. Full-grown larvae drop to the ground, enter the soil, and spin tough, reddish-brown cocoons in which they become adults or spend the winter as prepupae. In the South there may be three generations per year; in some Northern States and Canada there is only one. Population development can be monitored by use of a synthetic attractant *(1296)*.

The redheaded pine sawfly is one of the most widespread and destructive of the pine sawflies. It usually feeds on young trees, preferably those from 0.3 to 4.6 m tall *(769)*. Trees growing under stress on shallow soils, very wet or dry sites, or subject to severe competition from hardwoods, bracken fern, or other vegetation are especially susceptible to infestation, heavy defoliation, and damage *(31)*. Outbreaks occur frequently throughout the range of this sawfly.

A nuclear polyhedrosis virus formulated for field use at the Canadian Forest Pest Management Institute has proved to be effective in controlling the redheaded pine sawfly *(292, 1293)*. The native egg parasite, *Closterocerus cinctipennis* Ashmead, and the larval parasites such as *Spathimeigenia* spp. are also effective in helping to control this sawfly *(92, 342)*.

A number of management practices have been suggested for preventing damage in plantations by the redheaded pine sawfly: (1) Remove competing vegetation such as hardwoods or dense bracken fern before planting sites to hard pines; (2) avoid planting on high hazard sites covered with hardwoods or dense vegetation, in frost pockets, or on soils that are excessively wet, dry, or very low in nutrients; and (3) promote early closure of plantations by planting pines with spacing not greater than 1.8 by 1.8 m in the North Central States.

The **Virginia pine sawfly**, *N. pratti pratti* (Dyar), has been recorded from New Jersey and Maryland to North Carolina westward to Illinois. Its main hosts are Virginia and shortleaf pines; other pines are sometimes infested. Newly hatched, feeding larvae are pale green, with black head capsules, and are about 3 mm long. Full-grown larvae (fig. 180) are spotted or marked with longitudinal black stripes and are from 16 to 23 mm long.

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Figure 180.—Larvae of the Virginia pine sawfly, *Neodiprion pratti pratti*.

Winter is spent in the egg stage, and hatching occurs in early spring. Newly hatched larvae feed gregariously on the previous year's needles, beginning about 10 to 15 mm below the tip. Feeding in groups of 2 to 15 larvae each, they consume the outer portion of the needle, leaving the inner vascular tissue intact. After the first two instars, the larvae consume entire needles except for the basal portion within the sheath. They may also feed on portions of developing buds and on the tender bark of twigs. By mid-May they become full grown and drop to the ground. Here they spin cocoons in the surface litter or in the soil. Pupation occurs in September and the adults appear in October and November. Eggs are deposited individually within slits made by the female ovipositor along the flat sides of needles, usually before the end of November. There is one generation per year *(872, 1058)*.

Before the development of an outbreak in Maryland, Virginia, and North Carolina during the late 1950's, this species was not considered an important pest in the Middle Atlantic States. Surprisingly, the outbreak occurring at that time swept over more than 5.6 million hectares of pine and pine-hardwood type before it subsided. Tree mortality was not serious although some scattered killing was reported, but growth loss was severe.

White-footed mice and ants destroy large numbers of cocoons and prepupae in heavy infestations. The ichneumonid, *Exenterus nigrifrons* Rohwer, is an effective parasite of prepupae before they spin cocoons *(134)*. *Dahlbominus fuscipennis* (Zetterstedt), an introduced parasite of sawfly cocoons, has been released and established in infested stands in Virginia. A native polyhedrosis virus has destroyed up to 70 percent of sawfly larvae when applied from an airplane *(790)*.

Neodiprion pratti (Dyar) subsp., the **sand pine sawfly**, was detected in outbreaks in west Florida for the first time during 1977. Both Ocala and Choctawhatchee races of sand pine are hosts. Life stages are similar in appearance to those described for the Virginia pine sawfly, but the supraspiracular markings consistently blend into a black lateral stripe in mature, feeding larvae of the sand pine sawfly.

Winter is spent in the egg stage and hatching occurs during February and March, after which larvae feed on previous year's foliage, twig bark, buds, and strobili. Cocoons are spun in soil or duff during March and April, and turn dark brown. Adults emerge from cocoons during November and December and eggs are laid in shoots fully exposed to sunlight. Females typically lay two to three yellow eggs under the flat side and toward the apex of a needle. An average of about 30 needles per shoot is infested. There is only one generation per year.

Plantations 10 years old and older have been most subject to defoliation, especially along stand edges and within those stands of 750 or fewer trees per hectare. Defoliation exceeding 90 percent per tree has resulted in subsequently reduced tree growth and some tree mortality has occurred during spring droughts in association with infestations of cerambycid beetles. Known parasites include the ichneumonids, *Exenterus* spp. and *Endasys subclavatus* (Say), and a bombyliid, *Villa sinuosa sinuosa* (Wiedemann). Ice storms can cause heavy mortality in young larvae.

The **jack pine sawfly**, *N. pratti banksianae* Rohwer, occurs in Canada from New Brunswick to Manitoba, and in the Lake States. Jack pine is the favored host, but red and Scotch pines are occasionally attacked if they are growing with heavily infested jack pine. Full-grown larvae are yellowish green and about 22 mm long. The head is black and there are two longitudinal pale greenish-gray stripes running down the back. There is also a single row of 11 black spots on each side.

Winter is spent in the egg stage and hatching occurs in May or June. The larvae feed gregariously on previous year's needles only. Feeding is completed by early July. The larvae then drop to the ground and spin cocoons in the duff and top layers of the soil. Adults appear in late August and early September and lay three to five eggs in each needle, with the full complement of eggs on the needles of one twig. There is one generation per year.

Older, open-grown trees are more subject to infestation than young trees or trees in closed stands. Even-aged stands and plantations are especially attractive. Mortality from a single defoliation seldom occurs, but it may result from several successive defoliations. Generally, the most serious damage results from gradual reduction in vigor and growth of the affected trees. Late spring frosts and a polyhedrosis virus disease are often effective in the control of heavy infestations. Direct and preventive methods of control are discussed *(387)*.

Neodiprion pratti paradoxicus Ross has been recorded from Maryland to Nova Scotia and Ontario. Its hosts are pitch, Scotch, shortleaf, and jack pines. Full-grown larvae have black heads, and the body is marked with very pale lateral stripes. Supraspiracular spots are usually partially or entirely lacking in the middle of the body. Widespread outbreaks have occurred in pitch and shortleaf pine stands in New Jersey.

Neodiprion taedae taedae Ross, the **spotted loblolly pine sawfly**, has been recorded from eastern Virginia. Its favored host is loblolly pine, but it also occasionally feeds on shortleaf pine. Full-grown larvae are greenish white and about 22 mm long. The head is reddish brown, and there is a dull grayish-green longitudinal stripe on each side of the dorsum. There is also a row of black spots just above the spiracular line that extends from the second thoracic to the ninth abdominal segment, and there are two black blotches on top of the tenth segment.

Winter is spent in the egg stage, and hatching occurs in late April or early May. The larvae feed on old needles and reach maturity in about 30 days, fall to the ground where they enter the soil a few centimeters, and spin cocoons. Adults appear about mid-October and lay their eggs in rows on the sides of needles. There is one generation per year.

Since the new foliage is not eaten, infested trees are not completely defoliated or killed. Infestations occur more commonly in understocked pine stands where the trees retain their lower branches. The life history of this species was discussed under the name *N. americanum* (Leach) *(563)*.

The **loblolly pine sawfly**, *N. taedae linearis* Ross, long recognized as a pest of loblolly pine in Arkansas, is now known to occur also in Louisiana, southeast Texas, Mississippi, South Carolina, Missouri, Ohio, and Illinois. As far as known, loblolly and shortleaf pines are its only hosts; loblolly is preferred. Full-grown larvae are dull green and about 25 mm long. There are heavy black stripes along each side and often two lighter stripes below the heavier, black ones.

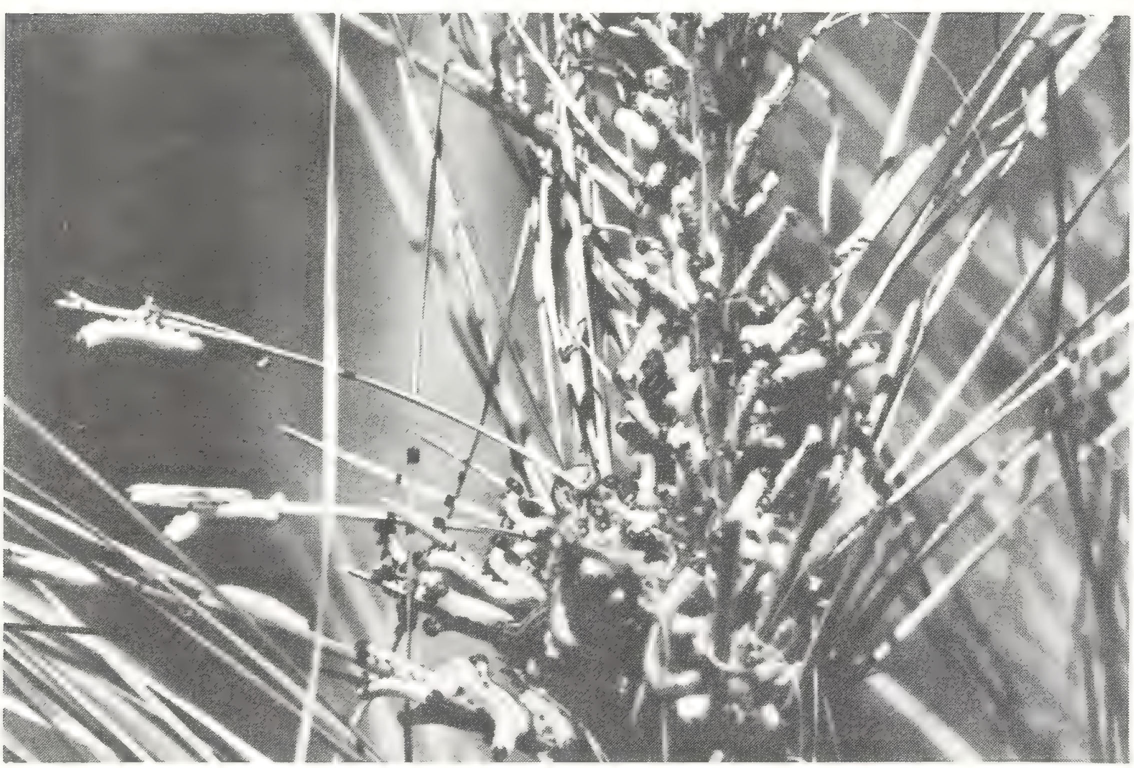
Winter is spent in the egg stage. Hatching occurs from early March to early May, depending on location. Young larvae feed gregariously in groups, often encircling the needles about half way from end to end, and partially girdling them. Infested terminals soon take on a reddened appearance. Older larvae feed singly or in pairs and consume the entire needle, leaving short stubs on the branch. They still retain their gregarious habit, however, and move in a group from branch to branch (fig. 181). For the most part, only the older foliage is eaten, but on shortleaf pine the terminal buds and tender bark on the new growth are also occasionally eaten *(256)*. Full-grown larvae drop to the ground and spin mahogany-colored cocoons in the

litter or topsoil. Pupation occurs in October or November and the adults emerge soon thereafter. Eggs are laid in slits cut into the needles, usually 2 to 10 per needle. Each female lays from 90 to 120 eggs, often all in the needles of one twig *(1251)*.

This sawfly is found chiefly on medium-size or large trees in forest stands. Several outbreaks have been recorded. One, which lasted four seasons, spread over an area of about 1.2 million hectares in Arkansas before it subsided. Trees suffering spring defoliation exceeding 75 percent per tree have shown an average net growth loss of 51 percent 1 year following defoliation and 29 percent the second year (fig. 182). Important natural control factors are a polyhedrosis virus disease, cold, rainy weather in the spring, and two larval parasites, a bombyliid, *Villa sinuosa sinuosa* (Wiedemann), and the ichneumonid, *Exenterus nigrifrons* Rohwer *(256, 1251)*.

Neodiprion warreni Ross is found in the Southeastern States from Arkansas into north Florida. Known hosts include spruce and shortleaf pines. Mature feeding larvae have a shiny black head and broad black subdorsal, lateral, and sublateral longitudinal stripes. Spaces between stripes are reduced to narrow, pale lines. Mature, feeding larvae have been collected during October in Arkansas and Florida.

The **Swaine jack pine sawfly**, *N. swainei* Middleton, one of the most important of the pine-infesting sawflies in eastern Canada, is known to have been present in the Lake States since the early 1950's. It is now widely distributed in the Upper Peninsula of Michigan, and in north-central Minnesota and Wisconsin. Jack pine is its favored host, but red, Scotch, and eastern white pines growing in close proximity to heavily infested jack pines are also subject to defoliation by migrating larvae *(1333)*. Full-grown larvae differ in color in different portions of the infested region. Those found in the Lake States have bright-orange heads and yellow bodies and there usually are two longitudinal, pale stripes on each side. Bright-yellow specimens without stripes are found occasionally.



F-486627

Figure 181.—Larvae of the loblolly pine sawfly, *Neodiprion taedae linearis*.

F-486626

Figure 182.—Large pines heavily defoliated by the loblolly pine sawfly, *Neodiprion taedae linearis*.

In the Lake States, winter is spent as prepupae in cocoons in the litter or topsoil, and pupation and adult emergence occur in early to late spring. Eggs are laid in the current year's needles, one to three eggs per needle, during June or July. The larvae are gregarious and feed primarily on old foliage, usually on exposed trees during July and August, until they become mature and drop to the ground. There is one generation per year *(80)*.

Numerous outbreaks have occurred at about 8-year intervals in jack pine stands in Ontario and Quebec, with foci in poorer jack pine sites on outwash plains *(803)*. Heavy tree mortality occurred in overmature stands and practically all surviving trees over many hectares remained stag-headed for several years. A sawfly population simulation model for such stands has been developed *(804)*. Some of the most severe infestations in the Lake States have occurred in jack pine plantations and windbreaks. Aerial application of a nuclear polyhedrosis virus spray has provided satisfactory control for at least 1 year in tests conducted in Quebec *(1095)*.

The **red pine sawfly**, *N. nanulus nanulus* Schedl, occurs in the Northeastern States west to Minnesota and in adjacent Canada. Its favored hosts are red and jack pines, but it also feeds on eastern white, Japanese red, and Swiss mountain pines. Full-grown larvae are dull grayish-green to black on top, greenish white beneath, and about 18 mm long. The head is black and two olive-green stripes run down the back to a darker area near the rear end. There are two longitudinal dark stripes on each side, with the upper one a little darker than the lower one.

Winter is spent in the egg stage. Hatching occurs in early May and larvae are present until July or August, depending on location. They are gregarious and usually consume all of the mature needles from one branch before migrating to another. Prepupae drop to the ground and spin cocoons in the duff. Adults emerge in early fall and deposit their eggs in slits in the round face of current season's needles near the tips of well-exposed branches. The female will usually oviposit her entire complement of eggs on one twig. There is one generation per year *(650)*.

Little or no mortality results from a single defoliation because only the older needles are eaten, but where defoliation continues for several years a high percentage of the affected trees may be killed. Overmature trees are particularly susceptible to damage.

The **white pine sawfly**, *N. pinetum* (Norton), occurs on eastern white pine throughout the range of its host in eastern North America. Pitch, shortleaf, red, and Swiss mountain pines are sometimes infested. Full-grown larvae are pale yellow and about 25 mm long. The head is black and four rows of black spots extend from the head to a black spot at the posterior end.

In the spring, the female deposits three to four eggs per needle, and the full complement is placed in the needles of a single twig. The larvae feed gregariously on both old and new needles, and when one branch is defoliated they migrate to another. When they reach maturity they drop to the ground, spin cocoons in the soil, and overwinter as a prepupa; pupation occurs in the spring. There is sometimes a partial second generation per year, depending on location.

The white pine sawfly attacks trees of all sizes both in plantations and in forest stands. Because the larvae feed on both old and new needles, they are capable of completely defoliating a tree. Widespread outbreaks occur occasionally, whereas local ones are reported almost every year. The egg parasite, *Closterocerus cinctipennis*, is sometimes an important natural control agent *(1011)*.

The **balsam fir sawfly**, *N. abietis* (Harris), occurs from coast to coast in southern Canada and Northern United States. Its favored host is balsam fir but it also attacks black and white spruces. Full-grown larvae are dark green and are from 18 to 25 mm long. The head is black and the body is marked with six longitudinal dark stripes or bands on the back, the lowest of which may be broken up into small dots or spots.

Winter is spent in the egg stage and hatching occurs in May or June. Newly hatched larvae feed gregariously on old needles, eating only parts of the needle. Feeding is completed in about 1 month. The mature larvae then spin tough, silvery or light-brown cocoons on the needles or in the litter on the ground. Adults appear from late July to early September and lay their eggs singly in slits cut in the edges of the needles. There is one generation per year.

Balsam fir growing in open stands, in pastures, along lakeshores in Ontario, and on islands off the coast of Maine is often heavily defoliated. Trees are seldom killed by a single defoliation but some are killed by repeated defoliations. Spruce trees in farm shelterbelts and ornamental plantings in the Prairie Provinces of Canada also have been damaged. The introduced parasite, *Dahlbominus fuscipennis* (Zetterstedt), has destroyed up to 40 percent of cocoons in the duff in Maine. Cocoons spun among the needles on the trees in the same stands escape parasitization.

Neodiprion abbotii (Leach) has been recorded in Ontario, Quebec, Wisconsin, Virginia, North Carolina, South Carolina, Georgia, and Florida. Its hosts are listed as loblolly, slash, longleaf, shortleaf, and red pines. The full-grown larva has a brown to black head with a light spot on the frons, and the thorax and abdomen are

pale green. There are also four dark-green to black lateral stripes. *N. abbotii* larvae feeding on slash and longleaf pines in south Florida have pale-amber head capsules and pale, longitudinal stripes.

Winter is spent as a prepupa in a cocoon and pupation occurs in the spring. Adults emerge as early as late March in the South. Eggs are laid in single rows of 15 to 20 each, mostly on previous year's needles, with the eggs of a row almost touching each other. Newly hatched larvae feed gregariously; older ones tend to feed singly. Prepupae spin tough, silvery-brown cocoons on the needles of the tree. There appear to be at least three generations per year in the South. First-generation larvae are found in May, second-generation larvae during July and August, and third-generation larvae from October to December *(564)*.

The **redheaded jack pine sawfly**, *N. rugifrons* Middleton, occurs in southern Canada and the Lake States where it feeds on jack pine. Mature feeding larvae are 15 to 20 mm long, have an orange-brown head, and two dark, subdorsal stripes run the full length of the body to a black patch on the last abdominal segment. A row of conspicuous black supraspiracular spots extends backward along each side from the prothorax to the ninth abdominal segment. The underlying body color is white.

Winter is spent as prepupae in the soil. Adults emerge annually in May and June, and oviposit in 1-year-old or older needles. Larvae of this early generation feed only on older foliage and damage to the host tree is slight. In those years when two generations develop, adults of the second generation emerge during July and August, oviposit principally in current-year needles, and larvae feed on foliage of all ages. The chemical basis for this feeding behavior is the presence of relatively high concentrations of two antifeedant organic acids in new foliage during the growing season *(624)*. When heavy infestations develop, jack pine may be almost completely defoliated by September or October and planted pines from 0.9 to 6.1 m tall may be killed. The tops of trees retaining 10 percent or less foliage often die the following spring. Trees in isolated plantations and windbreaks are most subject to severe damage *(1295)*.

The **brownheaded jack pine sawfly**, *N. dubiosus* Schedl, also occurs on jack pine with *N. rugifrons*, and is somewhat similar in biology and appearance. *N. dubiosus* differs principally in the underlying yellow color of larvae and in the first annulus of the adult female saw, which has less than 10 teeth. A comparison of these two species has been published *(82)*.

Neodiprion virginianus Rohwer is found in Virginia pine from the Piedmont of North Carolina north into southern Pennsylvania, west into eastern Kentucky, and on sand pine in peninsular Florida. Eggs are laid in a row underlying the round side of a needle, beginning near the point of needle divergence and ending near the apex. Mature, feeding larvae are relatively short and stocky with a shiny black head and a lateral-longitudinal row of distinct and evenly spaced subquadrate black spots. There are at least three generations per year in Florida. A 62-hectare outbreak occurred in the Tampa Bay area of Florida during the fall of 1978, resulting in growth loss and some tree mortality.

The **European pine sawfly**, *N. sertifer* (Geoffroy), an introduced species first recorded in North America at Somerville, N.J., in 1925 *(1060)*, is now widely distributed. It has been recorded from New England to southwestern Ontario, Michigan, Wisconsin, Ohio, Illinois, Iowa, South Dakota, and south to Missouri. It has many hosts, particularly Scotch, red, jack, Japanese red, Table Mountain, and Swiss mountain pines. Eastern white, Austrian, ponderosa, shortleaf, and pitch pines also are fed on to some extent when they occur in mixture with more favored species.

Full-grown larvae are grayish green and from 18 to 25 mm long. The head, thoracic legs, and upper part of the anal plate are black and there is a longitudinal light stripe down the back. There are also two light-green stripes and one intense green or black stripe on each side.

Winter is spent in the egg stage and hatching occurs from early April to mid-May. The larvae feed gregariously on the previous year's foliage and devour all of these needles on one branch before moving to another one. New needles are never eaten. Larvae may also feed on the bark of new shoots. This may result in shoot deformation or death *(1324)*. When the previous year's foliage on a tree is completely eaten before the larvae reach maturity, the tree is vacated and the larvae crawl to other trees to feed. Full-grown larvae either drop to the ground and spin tough, light to dark golden-brown cocoons in the duff, or they spin them in protected locations on the tree. Pupation occurs during late August or early September and the adults appear from early September to late fall. Eggs are laid in slits cut in the edges of current year's needles in needle clusters near the end of a branch. From 6 to 8 eggs are usually laid in a single needle, and about 10 to 12 needles in a single cluster are usually infested. There is one generation per year.

Trees defoliated by the European pine sawfly are seldom killed, since the new foliage is never eaten and the tree is never entirely stripped of its foliage. Bark feeding may cause some twig mortality but it is not serious. Losses in height and diameter growth may be severe, especially following repeated defoliations. Damage is most severe to Scotch pines grown in Christmas tree plantations.

During the late 1930's and early 1940's, colonies of the two European parasites, *Dahlbominus fuscipennis* (Zetterstedt) and another believed to be *Exenterus abruptorius* (Thunberg), were received from Canada for release in eastern infestations of this sawfly. *D. fuscipennis* became established in New Jersey and within a few years became rather abundant locally *(487)*. *E. abruptorius* also became established in New Jersey. So far, neither species has given adequate control. The European ichneumon, *Lophyroplectus oblongopunctatus (= luteator)* (Hartig) was released in Canada in 1962 and transferred to Wisconsin in 1979. It is established in both locations. A supply of a European polyhedrosis virus of the sawfly was also received from Canada for use in its control *(112, 113)*. It has proved to be very effective when applied as a spray either by aircraft or by knapsack or hydraulic sprayers (fig. 183). The literature on the biology, ecology, and control of the European pine sawfly has been reviewed *(687, 761)*.

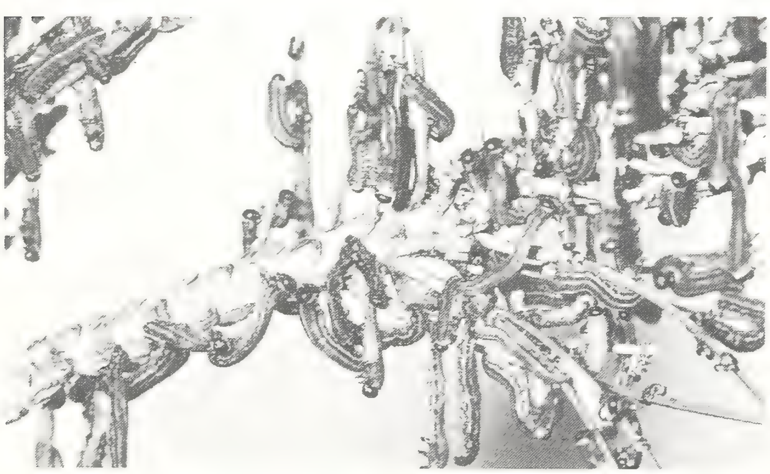


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Figure 183.—Colony of larvae of the European pine sawfly, *Neodiprion sertifer*. Larvae hanging head downward were killed by a polyhedrosis virus.

The **blackheaded pine sawfly**, *N. excitans* Rohwer, occurs from Virginia to Florida and west to Arkansas and Texas. It also occurs in Central America *(1297)*. Loblolly and shortleaf pines are its preferred hosts in the United States. Slash, longleaf, pond, spruce, sand, and Sonderegger pines are also attacked but to a much lesser extent *(1194)*. The full-grown larva is olive green and about 25 mm long (fig. 184). Its head is glossy black, there are two longitudinal black stripes on the dorsum, a row of black spots on each side, and a large black spot on the last abdominal segment.

F-514368

Figure 184.—Larva of the blackheaded pine sawfly, *Neodiprion excitans*.

Winter is spent mostly in cocoons, but occasionally in the egg state or as older larvae *(1292)*. Oviposition begins in March when each female lays one egg per needle in individual pockets sawed just above the fascicle sheaths of needles on a given shoot. Newly hatched larvae are gregarious, with a circle of larvae feeding on a single needle. Older larvae feed in steadily decreasing numbers per needle. Previous year's foliage is preferred during the growing season, but all foliage may be consumed when needle growth ceases during the fall. When a branch or tree is heavily defoliated, the larvae migrate in groups to other branches or trees. Full-grown larvae spin golden-brown cocoons in ground litter or topsoil, but sometimes remain on the tree and spin their cocoons on twigs, needles, or in bark crevices on the lower trunk. There are three to four generations per year in the Gulf region *(564, 565, 1194)*.

Heavy infestations typically develop during the fall in moderate to dense stands of sawtimber, especially when overmature trees are present. Overwintering trees stripped of more than 90 percent of their foliage suffer growth loss and may be attacked and killed by *Ips* engraver beetles, the black turpentine beetle, cerambycid

beetles, and ambrosia beetles. Several large outbreaks have occurred in Florida and Texas; however, they subsided after one or two seasons. Starvation and reduced reproductive capability of the females are among the factors that help bring outbreaks to an end. The ichneumonid, *Endasys subclavatus* (Say), is an effective parasite attacking cocoons spun in the litter and topsoil *(342)*, while the pteromalid, *Dibrachys cavus* (Walker), commonly attacks cocoons spun above ground.

The **slash pine sawfly**, *N. merkeli* Ross, is known to occur in Georgia, Florida, Mississippi, and on Grand Bahama Island. Both varieties of slash pine are hosts in the United States, and Caribbean pine is infested in the Bahamas. Full-grown female larvae are 25 to 30 mm long, with brown subdorsal and supraspiracular stripes, and two widely separated, black semioval spots near the posterior end. The head is 2.3 to 2.5 mm wide, reddish above the eyes and sooty black below. This two-tone coloration is most evident in alcohol-preserved larvae. Eggs are laid in growing, current year's needles, with a row of 10 to 15 egg pockets typically underlying the flat side of a needle, beginning at the fascicle sheath *(1294)*.

Winter is spent as a prepupa in dark mahogany-brown cocoons usually spun in the soil. Adult emergence occurs approximately during May, July, and September in Florida. Larvae feed only on old foliage during the growing season, but may completely defoliate trees during the fall when the largest populations typically develop. Extensive fall outbreaks have occurred in 5- to 10-year-old open plantations growing on periodically flooded flatwood sites in Florida and Mississippi, subsequently resulting in greatly reduced tree growth when defoliation exceeds 90 percent per tree. Outbreaks in south Florida have been terminated within one growing season by a nuclear polyhedrosis virus disease. Flies in the genus *Spathimeigenia* are important parasites attacking mature, feeding larvae *(342)*, and *Villa sinuosa sinuosa* (Wiedemann) is an important cocoon parasite during droughts. Chance flooding of cocoons immediately following adult sawfly emergence resulted in complete mortality of parasitoids within cocoons, followed by a large outbreak of this sawfly in south Florida.

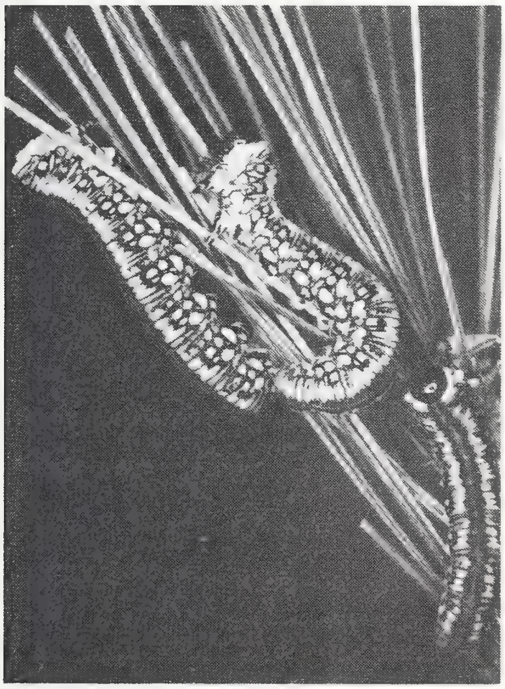
A number of other species of *Neodiprion* also occur in eastern forests: *N. nigroscutum* Middleton occurs on jack pine in the Lake States and Ontario. Mature, feeding larvae have reddish-brown heads, unbroken subdorsal and supraspiracular stripes, and arcuate markings above the legs. An epiproctal spot is not present *(81)*. *N. pinusrigidae* (Norton) feeds on pitch pine from New Jersey to Maine. Full-grown feeding larvae are dull green with a black head, solid black subdorsal stripe, and broken black lateral stripe. Sometimes a double row of black dots occurs below each lateral stripe. *N. hetricki* Ross has been observed feeding on loblolly pine in Virginia and North Carolina and pond pine in South Carolina. Mature, feeding larvae have black heads, black subdorsal stripes, and black lateral stripes that may be either broken or solid. There is a single generation each year in Virginia, with females depositing overwintering eggs during October *(564)*. *N. compar* (Leach) is reported from southeastern Canada, Virginia, Georgia, and Florida. Known hosts include red and jack pines in Canada and longleaf pine in Florida. Mature feeding larvae from Florida are pale green, with barely discernible longitudinal stripes. The pale-amber head bears a yellow triangular spot within a large black pentagonal marking. *N. maurus* Rohwer occurs on jack pine in southeastern Canada and the Lake States.

The genus *Diprion* is represented by only one species in the United States and Canada, and this species is of foreign origin.

The **introduced pine sawfly**, *D. similis* (Hartig), was first recorded in New Haven, Conn., during 1914, and spread to western Wisconsin by 1944 *(241)*. It was first found in North Carolina during 1977 and by 1981 had been detected in two distinct outbreaks covering 24,000 square kilometers in North Carolina, Tennessee, and Virginia *(339, 474)*. It is now known to occur from Maine to North Carolina, in the Central and Lake States, and in southern Ontario and Quebec. Eastern white pine is the favored host but Scotch, jack, red, and Swiss mountain pines are commonly reported secondary hosts. Shortleaf and Virginia pines are also attacked but are not considered to be threatened.

Full-grown feeding larvae (fig. 185) are about 20 to 25 mm long, with shiny black heads. The body has a double black stripe bordered by yellow along the dorsal midline, and the sides are dark with numerous rounded yellow and white spots. Ventrally the larvae are pale yellow. Cocooned larvae have gray heads; the body is pale gray-green and bears markings similar to those of feeding larvae, but much lighter. The pupa is light green. Cocoons are cylindrical with rounded ends and relatively thick, tough walls that vary from very light to dark brown in color.

Winter is spent as cocooned larvae. Pupation occurs in early spring and adults emerge principally during May and early June. The females produce a potent sex attractant *(239)*. Eggs are laid in rows of about 10 per needle, each deposited in a slit cut into the edge of the needle (fig. 186). Young larvae feed gregariously; older larvae, singly. First-generation larvae prefer to feed on previous year's needles, while larvae of the second generation eat both old and new needles. Young larvae eat only the outer, tender parts of needles; older larvae consume entire needles and will feed on twig bark when most of a tree's foliage has been consumed. Both first- and second-generation cocoons are spun in crown foliage, at the base of small branches, in bark crevices on the trunk, on host or nonhost trees, shrubs, grasses, or other understory objects. Pupation occurs mainly during July, and second-generation larvae feed through September. Small numbers of third-generation adults (mostly males) are reported to emerge during some years in Wisconsin, but most



Courtesy H. C. Coppel, Univ. Wis.

Figure 185.—Larvae of the introduced pine sawfly, *Diprion similis*.

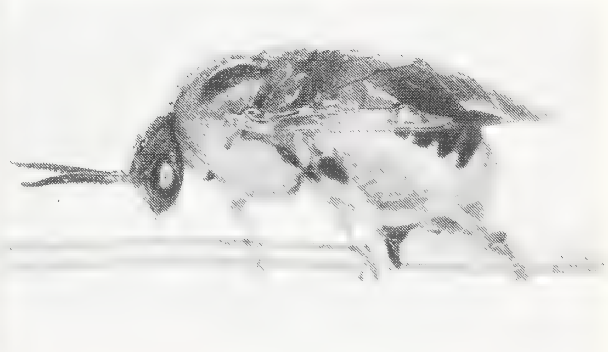


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Figure 186.—Introduced pine sawfly, *Diprion similis,* ovipositing in eastern white pine needles. Eggs of this species are covered with a pulpy mass.

second-generation sawflies overwinter as diapaused larvae within cocoons. Because of its variable development, all stages of this sawfly may be present at the same time during the summer *(241, 474, 846, 1325)*.

Defoliation is usually most severe in the upper half of tree crowns, but heavily infested trees may be completely defoliated in one season. When this happens late in the season after the winter buds have formed, many branches and occasionally trees may be killed.

Some factors in natural control include very low or rapidly fluctuating temperatures or heavy rainfall during the egg and early larval stages, bird predation of cocooned larvae, and the establishment of three European parasitic wasps. The ultimate-stage larval parasitoid, *Exenterus amictorius* (Panzer), and two cocoon parasitoids, *Dahlbominus fuscipennis* (Zetterstedt) and *Monodontomerus dentipes* (Dalman), are important control agents in Wisconsin *(241)*. Suppression of the introduced pine sawfly to low population levels in North Carolina was achieved by 1982, primarily through mass-rearing and augmentative releases of *M. dentipes* *(474)*.

A comprehensive review of the European and North American literature on *D. similis* is available *(241)*.

The genus *Gilpinia* is represented by two species in the United States and Canada and both are of foreign origin.

Gilpinia frutetorum (F.) was discovered in North America in Massachusetts and Rhode Island in 1932, and now occurs in Quebec, from Maine south to New Jersey, Pennsylvania, Wisconsin, and Minnesota. Its favored hosts are red and Scotch pines, but it may also attack various other hard pines. Full-grown larvae are light green with reddish-brown heads and are about 20 mm long. The body is marked with six longitudinal dark-green stripes, two on the dorsum and two on each side (fig. 187).

Winter is spent as a cocooned prepupa and pupation occurs in the spring. Adults appear from late May to late July. Eggs are laid in slits cut in the needles. The larvae feed singly, preferably on the older needles. Because of their greenish color they blend into the background and are difficult to see. The first sign of infestation usually is the presence of frass and green needle fragments on the ground beneath the tree. Heavy infestations occur occasionally in pine plantations *(1061)*.

The **European spruce sawfly**, *G. hercyniae* (Hartig), was first recorded in North America near Ottawa, Canada, in 1922. It has spread throughout the eastern spruce

F-519578

Figure 187.—Larvae of *Gilpinia frutetorum*.

forests from Newfoundland to Pennsylvania and west to Minnesota and Manitoba. White spruce appears to be the favored host; however, red, black, and Norway spruces also are attacked. Young larvae are yellowish green; older feeding larvae are darker green, marked with five longitudinal white lines, and about 20 mm long (fig. 188). The white lines are absent and the body is somewhat shortened in cocooned larvae.

Courtesy Can. For. Serv., Gt. Lakes For. Res. Cent.
Figure 188.—Larva of European spruce sawfly, *Gilpinia hercyniae*.

In the Northeastern States there may be one or two generations per year or a partial third, depending on location. Farther north there is only one. In the Northeastern States, adults of the first generation appear from early May to June. Males are rare and reproduction is parthenogenetic. Eggs are laid in slits cut in old needles and hatching occurs within a few days. Larvae of all ages feed singly. Young larvae feed by chewing out small pieces of the needle or by eating all but the vascular bundle. Older ones consume the entire needle. Old needles are usually preferred, but full-grown new needles may be eaten also. Second-generation adults appear in early July or later and lay their eggs in needles. Hatching occurs shortly thereafter, and the larvae feed for 3 or 4 weeks. At maturity, they drop to the ground and spin cocoons in the litter in which they spend the winter. In the northern portion of the species' range, some remain in diapause for several years before pupating *(999)*.

The European spruce sawfly found conditions favorable for a rapid increase in numbers once it gained a foothold in the spruce forests of North America. In 1932, serious infestations were found over an area of about 5,200 square kilometers of the Gaspé. Two years later evidence of defoliation was also apparent in Quebec, New Brunswick, and adjacent areas in the United States. By 1935, the Gaspé outbreak covered about 15,500 square kilometers, and tree mortality in some areas had reached serious proportions. Collapse of the outbreak by 1942 was caused by an accidentally introduced nuclear polyhedrosis virus disease *(49)*. Since then populations have fluctuated at very low levels, and the spruce sawfly is no longer considered to be an economic pest *(913)*.

During the 1930's and 1940's, the Canadian government imported and liberated approximately 20 species of parasites in infested areas *(788)*. Substantial numbers of these parasites were also released in the United States. Two species of cocoon parasites and five species of larval parasites became established *(328)*.

Family Tenthredinidae
Sawflies

The family Tenthredinidae is represented by more than 730 species in the United States and Canada. The larvae are all leaf feeders, leafminers, gall formers, or fruit borers. Many species are important pests of forest and shade trees and forest plantations.

The antennae of the adults most commonly have nine segments in the Eastern United States and range in shape from setaceous and filiform to clavate. The mesothorax is without sterno-pleural sutures, the anterior of the scutellum is V-shaped, and the posterior margin usually has a distinct posttergite. The tibiae are without preapical spurs, and the apical spurs of the front tibiae usually have the longer spur cleft at the apex. The larvae range in length from 10 to 37 mm and are usually largest in diameter at the thorax. The body is greenish or variously colored, sometimes with distinct markings, and is either smooth, glabrous, setiferous, tuberculate, or spinous *(1041, 1369)*.

Heterarthrus nemoratus (Fallén), the **birch leafmining sawfly**, an introduced species first recorded from Nova Scotia during 1908, is now widely distributed in the Northeastern United States and southeastern Canada *(1097)*. Its hosts are various species of birch, with gray, paper, yellow, and European white being preferred. The full-grown larva is somewhat flattened and whitish, with the head and joints of the thoracic legs brownish, and is about 10 mm long.

In Maine, winter is spent in the prepupal stage and pupation occurs in late spring. Female adults (no males have been found) appear during June and early July and deposit their eggs singly in slits cut in the edges of mature leaves, apparently at all levels in the tree. The larvae feed in the tissues between the upper and lower surfaces of the leaf, producing large blisterlike or blotch mines free of frass (fig. 189). Each full-grown larva constructs a cocoon within its mine. The leaf then falls

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Figure 189.—Mines and cocoons of *Heterarthrus nemoratus*, the birch leafmining sawfly, in leaf of paper birch.

to the ground and the prepupa remains in its cocoon throughout the winter. There is one generation per year *(977)*.

Heavy infestations of the birch leafmining sawfly occurred in Maine during the 1920's and 1930's, and severe defoliation of birch occurred in many areas. Very little tree mortality occurred, but there was a considerable loss in annual growth. During this period several species of parasites were imported against the sawfly *(327)*, two of which, *Chrysocharis laricinellae* (Ratzeburg) and *Phanomeris phyllotomae* Muesebeck, became established.

The **birch leafminer**, *Fenusa pusilla* (Lepeletier), an introduced species first recorded from North America in Connecticut in 1923, now occurs from Newfoundland to Maryland, west to Ontario, Minnesota, and Iowa; also in Washington and Oregon *(1097)*. Full-grown larvae are somewhat flattened, yellowish white in appearance, and about 6 mm long. Black spots occur on the venter of the thorax and the first abdominal segment.

Pupation occurs in the spring and the adults begin to appear about mid-May. Eggs are deposited singly in slits cut in the central areas of young leaves, usually near the tips of branches. The larvae feed on the tissues between the leaf surfaces. At first they feed singly, forming small kidney-shaped mines near the egg. As the individual mines increase in size, they coalesce and form large, hollowed-out brown areas in the leaf. These areas (fig. 190) wrinkle and turn brown. Full-grown larvae chew their way out of the leaf and drop to and enter the ground where they form small earthen cells, 2.5 to 5 cm below the soil surface, in which they overwinter as prepupae in cocoons. There are three or four generations per year in the southern part of the range of this leafminer *(450)*.

Outbreaks occur frequently in the Northeastern States and result in the browning of birch stands over wide areas. Some trees may be killed, but the greatest damage is the weakening of affected trees, which leads to attack by other insects.

Courtesy Conn. Agric. Exp. Stn.

Figure 190.—Mines of the birch leafminer, *Fenusa pusilla*, in leaves of gray birch.

The **elm leafminer**, *F. ulmi* Sundevall, an introduced species, occurs in southeastern Canada and the Northeastern United States west to the Lake States. Its preferred hosts are English, Scotch, and Camperdown elms. American elm is also attacked occasionally. Full-grown larvae are about 6 mm long, flattened, and whitish with a greenish cast. The head is brown and the legs are encircled with brown.

Winter is spent as prepupae in brown papery cocoons in the topsoil. Pupation occurs in the spring and the adults appear in May, usually during the first half of the month. Eggs are laid in the upper surfaces of leaves. The larvae mine the tissue between the leaf surfaces, causing large blotch or blisterlike mines. Several attacks may occur on a single leaf. When this happens, the various mines may coalesce and the entire leaf be hollowed out (fig. 191). These leaves soon wither and fall. Where only a small portion of a leaf is mined, the surfaces dry out and crack, leaving holes in the leaf. The larvae usually become mature in late June. Then they vacate their mines and drop to and enter the ground to spin their cocoons. There is one generation per year *(1097)*. This species appears to be most injurious to small trees in nurseries and ornamental plantings.

Courtesy Conn. Agric. Exp. Stn.

Figure 191.—Mines of the elm leafminer, *Fenusa ulmi*, in elm leaves.

The **European alder leafminer**, *F. dohrnii* (Tischbein), an introduced species, occurs in southern Canada and the Northern United States. Its hosts are listed as alders, especially the introduced European alders. Winter is spent in the prepupal stage in cocoons in the ground. Pupation occurs in the spring, and the adults appear and lay eggs during late May and early June. Larvae feed in the tissues of the leaf for about 3 weeks, forming blotch mines *(1097)*. Up to 12 larvae may feed on a single leaf. Full-grown larvae drop to the ground to pupate, and a second generation of adults appears from late July to early September. They also lay eggs and give rise to a second generation of larvae. These become full grown by late fall and then enter the ground for the winter.

Profenusa thomsoni (Konow), the **ambermarked birch leafminer**, possibly an introduced species from Europe, is widely distributed in Quebec, Maine, Vermont, Connecticut, Ontario, Wisconsin, Illinois, and Manitoba. Its hosts are gray, paper, and yellow birches. This leafminer is one of the four sawflies that feeds in leaves of *Betula* spp. *(1097)*. In Ontario, female adults were observed in late July and early August. Eggs are laid in the tissues of leaves. The larvae mine the tissues, forming light-colored blotch mines. Up to 40 larvae inhabit a single mine. When all of the tissues of a leaf are consumed, all of the larvae, regardless of age, vacate the mine and drop to the ground. Of these, only those in the latter part of the fifth instar are able to enter the soil and survive. In light infestations, sucker growth up to about 1.2 m tall in shaded locations is preferred. In contrast, trees up to 10.7 m tall in all types of habitats are attacked in heavily infested areas. Damage is not considered serious because defoliation occurs late in the season *(821)*.

Profenusa alumna (MacGillivray) has been observed mining the leaves of oak, primarily red oak, from Maine to Virginia west to Wisconsin and Illinois. Full-grown larvae are about 6 mm long and have prognathous, octagonal heads more than twice as wide as long. Winter is spent as prepupae in cells in the duff. Adults appear in the spring and the female lays her eggs on the upper surfaces of the leaves. The larvae bore into the leaf and mine the tissues, causing blotching and severe browning. Heavily infested leaves may drop by September, leaving bare branches in the top of the tree. Although males have not been collected in Maine, they have been taken in other areas of its range *(1097)*.

Profenusa canadensis (Marlatt), the **hawthorn leafmining sawfly**, has been recorded mining the leaves of hawthorn and cultivated cherry. It is widely distributed in eastern North America *(1097)*. Serious infestations have occurred in Massachusetts and New York. *P. lucifex* (Ross) attacks white oak in Maine, New York, and Illinois, and bur oak in Ontario *(737)*.

Messa populifoliella (Townsend), the **poplar leafmining sawfly**, mines the leaves of poplar from New Brunswick southwestward to New Mexico and west to California, also in South Dakota and Manitoba *(1097)*. In New Brunswick, adults are present the latter part of May. Females oviposit generally near the leaf tip. Larvae feed for 2 to 3 weeks, making blotch mines. They then drop to the soil to overwinter and pupate *(1217)*.

The **pear sawfly**, *Caliroa cerasi* (L.), an introduced species, occurs from coast to coast in southern Canada and the Northern United States. Although best known as a pest of cherry and pear in the United States, it also feeds occasionally on hawthorn, plum, quince, mountain-ash, black cherry, and serviceberry. Full-grown larvae are tadpole-shaped, sluglike, and about 12 mm long. The body is covered with a shiny, olive-green material secreted by the larva.

Winter is spent in earthen cells lined with a substance secreted by the larvae. Pupation occurs in June. Eggs are deposited singly in small semicircular slits cut in the leaf tissue. The larvae feed mostly on the upper surface of the leaf, eating the parenchyma only. Heavily infested trees appear as if scorched, and their leaves drop prematurely. Full-grown larvae drop to the ground and form cells in the soil in which pupation occurs. Reproduction is parthenogenetic *(1097)*. Females appear in 2 or 3 weeks and lay eggs. Larvae of this generation are present in August and September. When they become mature, they also drop to the ground. There are two generations per year throughout most of the range of this sawfly.

The **scarlet oak sawfly**, *Caliroa quercuscoccineae* (Dyar), has been recorded from scarlet, black, pin, and white oaks from Maine to North Carolina west to

Minnesota, Illinois, Missouri, and south to Louisiana. Full-grown larvae are shiny green and about 12 mm long. Adults appear to be most numerous in October. Eggs are laid in slits cut in the lower surface of the leaf. They are placed singly in rows along the sides of the midribs and larger veins, and all hatch within a few days after being laid. The larvae feed on the epidermis of the leaf, leaving it almost colorless and transparent. Evidence of feeding is apparent during late summer. There may be two generations per year, and the winter may be spent in the larval stage *(74)*.

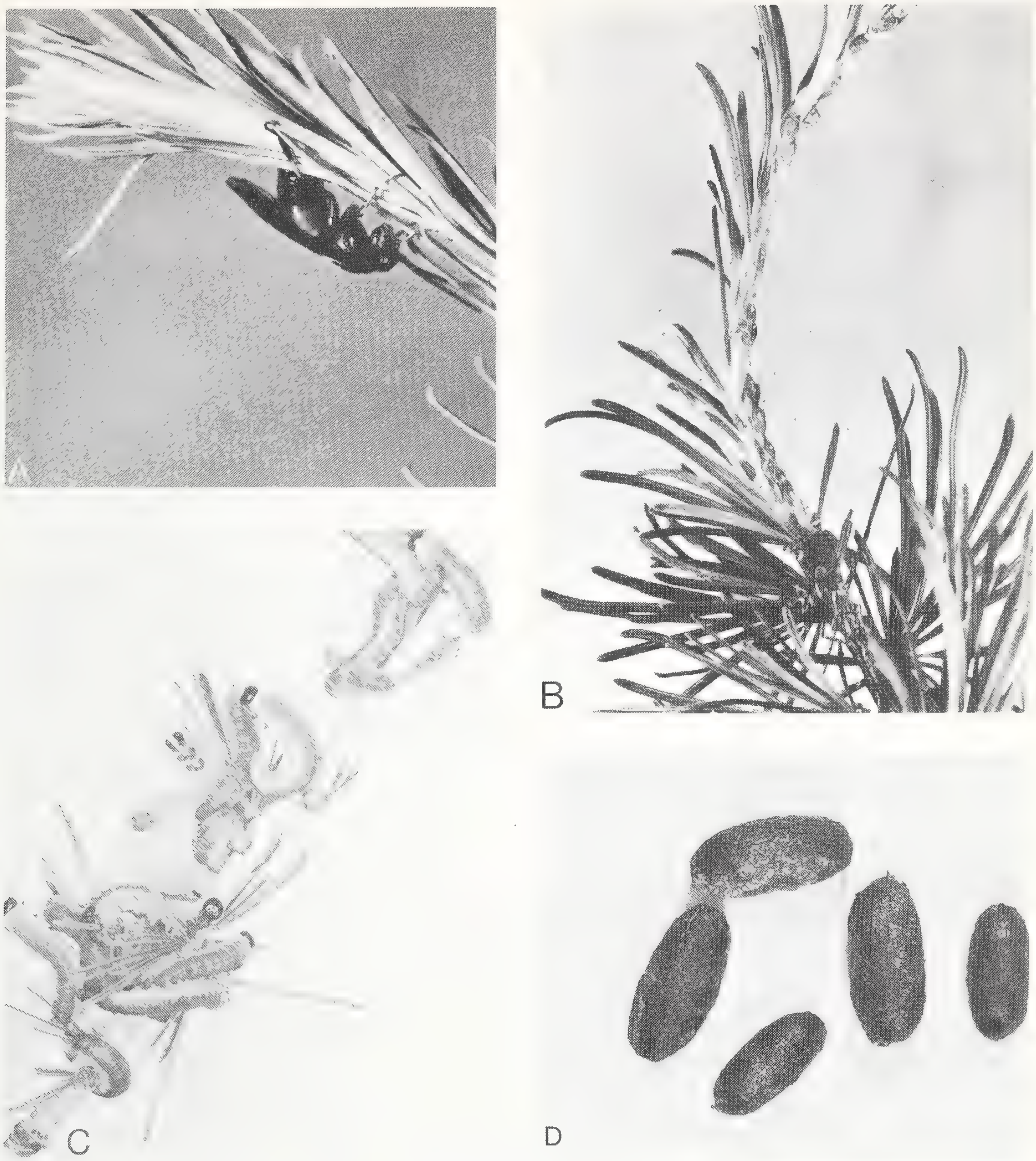
Caliroa petiolata Smith occurs on pin oak in New Jersey. Three other species of *Caliroa* are known on oaks, one on tupelo, one on chestnut, and one on *Prunus* spp.

The genus *Periclista* is represented in eastern forests by 10 species that feed on the leaves of oaks and hickories. The larvae are usually light green or have the dorsum grayish, and are armed with rows of small, single spines that may be simple or forked.

The **larch sawfly**, *Pristiphora erichsonii* (Hartig), was first recorded in North America in 1880. It now occurs in all Canadian Provinces, in Alaska, and all of the northern tier of States plus Maryland, North Carolina, and West Virginia. Its hosts are listed as tamarack and Western, subalpine, European, Japanese, Dahurian, and Siberian larches. In eastern America, tamarack is most seriously infested, but planted exotic larches are coming under increasingly serious attack. Full-grown larvae are whitish beneath and gray-green along the dorsum, have jet-black heads, and are about 16 mm long. Female adults are black and from 6 to 9 mm long. The abdomen has a broad orange or red band, tapers sharply posteriorly, and is keeled longitudinally along the midventral line.

In the Lake States, winter is spent in the prepupal stage in the ground. Pupation occurs in the spring and the adults appear from mid-May to August, depending on temperature and location. Eggs are laid in rows under the bark of currently elongating shoots on the branches, and hatching occurs in about 8 days. The emerged larvae move to and feed in groups upon tufts of needles, which are found on short shoots on the older twigs. Feeding is completed in about 20 days and mature larvae drop to the ground, enter the duff, and spin papery, brown cocoons. Because of the long period of adult emergence, feeding larvae, cocooned larvae, pupae, adults, and eggs all may be found at the same time in early summer (fig. 192). There is one generation per year, but occasionally small numbers of second-generation adults are produced too late for any larvae to complete feeding. A small number of larvae enter diapause and require 2 years to complete one generation *(332, 496)*.

Because larvae have the feeding behavior of rejecting single needles found on elongating shoots in favor of needle tufts found on short shoots, 100 percent defoliation seldom occurs. The chemical basis for this differential feeding appears to be the presence of relatively high concentrations of five deterrent chemicals in single needles from mid-July into August *(945)*. Heavily defoliated trees commonly refoliate after a few weeks; however, repeated defoliations can result in trees with thinned foliage, reduced radial and terminal growth, reduced production of normal shoots with a tendency toward adventitious growth, and branch mortality. Marked loss of radial increment occurs after 4 to 6 years of outbreak, and tree mortality occurs after 6 to 9 years of moderate to heavy defoliation. Many widespread outbreaks have been recorded since 1880 and losses have been severe. Since the middle of the 1950's, an estimated volume loss of 40 percent in valuable sawtimber and pulp stands has occurred in managed forests in Minnesota.



A, F-485946; B, F-485947;
C, F-531261; D, F-531899

Figure 192.—The larch sawfly, *Pristiphora erichsonii*. A, ovipositing female; B, eggs in new shoot; C, mature larvae; D, cocoons.

Overwintering cocooned sawfly larvae are destroyed in enormous numbers by small mammals, especially shrews and voles. High surface water in tamarack bogs also destroys large numbers of cocoons at times. A moderate number of species of parasites occur but only two, the imported ichneumonid *Mesoleius tenthredinis* Morley and the tachinid *Bessa harveyi* (Townsend), have been common during the current outbreak in central Canada and Minnesota, which began about 1938. Initially, *M. tenthredinis* was quite effective in control; however, the sawfly developed an immunity to it in central Canada, Minnesota, and Wisconsin *(335)*.

In 1961, the ichneumonid *Olesicampe benefactor* Hinz was introduced from Europe to Canada; this has added a very promising parasite to the biota for control of the larch sawfly. This parasite was first established in the Prairie Provinces, transferred eastward in Canada, and then to several locations in the Central and Eastern United States *(341, 704, 1216)*.

The **mountain-ash sawfly**, *P. geniculata* (Hartig), a probable introduction from Europe, was first recorded in North America at Haines Falls, N.Y., in 1926 *(1059)*. It is now recorded from the Northeast to Minnesota, southeast to West Virginia, and Newfoundland to Ontario. Its principal hosts are American and European mountain-ashes. It also occurs occasionally on showy mountain-ash and the hybrid, *Sorbaronia*. Full-grown larvae are pale greenish to yellow with yellow heads and yellow thoracic legs. All body segments except the last are marked with black spots of uneven size and shape (fig. 193). The spots occur in irregular rows, four along each side of the body and two broken ones down the dorsum.

In eastern Canada, winter is spent in the prepupal stage. Pupation occurs in the spring and the adults appear from late May to early July. Eggs are deposited in slits cut around the edges of leaflets and hatching occurs in about 1 week. Newly hatched larvae straddle the edge of the leaf and feed around the periphery. When disturbed they raise their abdomens in the form of an S. Larvae in the first two stages are gregarious. Fourth and fifth instars often feed singly. They usually consume all of a leaflet except the midrib. When they have consumed one leaflet they move to another. Feeding is completed in about 2 or 3 weeks and the larvae drop to the ground. Here they spin cocoons in the duff and topsoil. About 20 percent of these pupate and appear as second-generation adults in July *(432)*.

The mountain-ash sawfly is primarily a pest of shade and ornamental trees. The esthetic value of these trees is seriously reduced by defoliation, but they usually survive even when completely defoliated.

Other species of *Pristiphora* occurring in eastern forests include *P. chlorea* (Norton) on oak, *P. siskiyouensis* Marlatt on birch, and *P. sycophanta* Walsh on willow.

The **yellowheaded spruce sawfly**, *Pikonema alaskensis* (Rohwer), is widespread, occurring from Newfoundland to Alaska, Massachusetts, Michigan, Minnesota, Wyoming, Idaho and British Columbia. Its hosts are white, black, red, blue, Norway, and Engelmann spruces *(1320)*. Full-grown larvae (fig. 194) are olive green above and lighter green below and are about 18 mm long. The head is chestnut brown or reddish yellow and is sometimes mottled with various shades of brown. Each side of the body bears a gray-green longitudinal stripe near the midline of the dorsum, a broad one beneath this, and a darker one farther down. There is also a dark line or spot just above the base of each leg.

Winter is spent as prepupal larvae in tough, dark-brown cocoons. Pupation occurs in the spring, and the adults appear from late May to mid-June. Eggs are deposited in slits cut in current season's needles, usually at the base and usually only one per needle. Sometimes they are also found in the tender bark of the stem between needles. There are five feeding instars in males and five or six in females *(1228)*. Larvae prefer to feed on new needles, but older larvae will eat old needles when new foliage is lacking. No significant differences in the susceptibility of white spruce from different seed sources has been found *(237)*. The larvae become full grown in early to late July and drop to the ground. Here they spin cocoons in the duff or top 2 cm of soil. There is one generation per year *(906)*.

The yellowheaded spruce sawfly is a serious defoliator of young spruce plantations and natural reproduction growing in open areas; ornamental, shelterbelt, and nursery spruces are also infested. Young plantation trees are usually not attacked until the 3rd to 5th year after planting; trees older than 5 years may be killed after 3 or 4 consecutive years of moderate to heavy defoliation. Small mammals and other predators as well as numerous insect parasites are important causes of mortality in

Courtesy Can. For. Serv.

Figure 193.—Larvae of the mountain-ash sawfly, *Pristiphora geniculata.*

Courtesy Can. For. Serv., Gt. Lakes For. Res. Cent.

Figure 194.—Larvae of the yellowheaded spruce sawfly, *Pikonema alaskensis.*

late-stage feeding larvae and cocooned populations *(607, 1202)*. An attractant involving female and synergistic host components has recently been identified *(60, 61)*.

The **greenheaded spruce sawfly**, *P. dimmockii* (Cresson), is recorded from Newfoundland to Northwest Territories, New Hampshire, Colorado, Wyoming, and Idaho, and feeds on various species of spruce. Populations are usually low and apparently cause little injury.

The **willow sawfly**, *Nematus ventralis* Say, occurs in southeastern Canada, south to Georgia, and west to Utah, Colorado, and Montana. Its favored host is willow, but it also feeds on poplar. Full-grown larvae are black or greenish-black, with large light-yellow spots on the sides of the body, and are about 18 mm long.

Winter is spent in the prepupal stage in cocoons in the litter or topsoil beneath the trees. Pupation and adult emergence occur in the spring. Eggs are deposited in pockets cut in the tissues of the leaves. Young larvae feed in colonies, eating small holes in the leaves. Later, entire leaves are eaten. There may be one to several generations per year, depending on location. Some individuals may remain in diapause up to 20 months before completing their development, especially in northern areas.

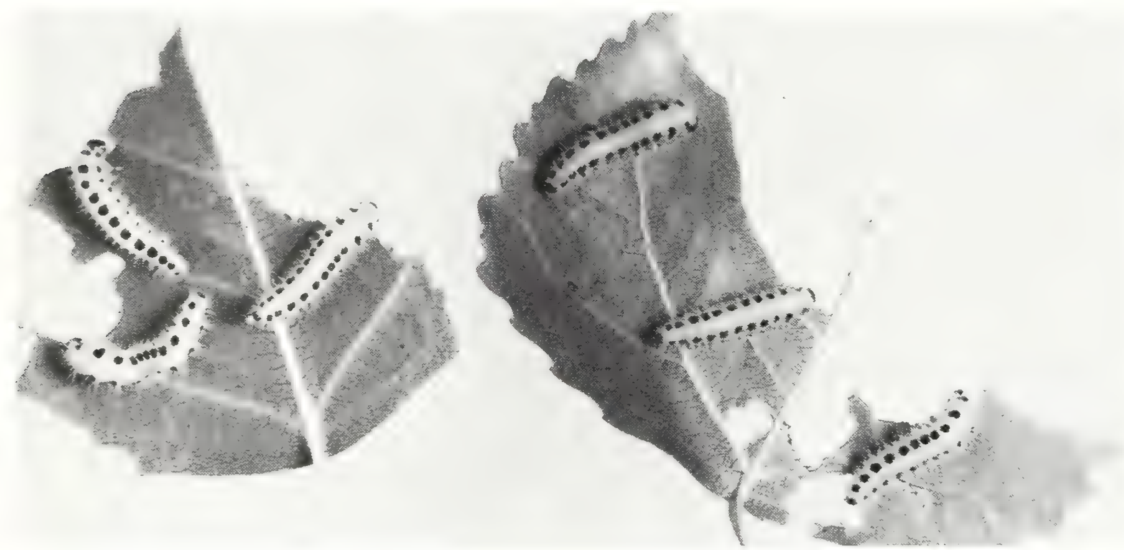
The willow sawfly occasionally heavily defoliates willows in ornamental plantings and along streams. Basket willows in the South have been damaged severely.

Nematus salicisodoratus Dyar occurs from Maine to Virginia, west to Wisconsin, Illinois, and Arkansas. It also feeds on willow and poplar. Full-grown larvae are light green and about 15 mm long. The head is black and there are three longitudinal rows of closely spaced black spots on the dorsum. There are also two rows of black spots on each side; those in the lower row are larger. Winter is spent in the prepupal stage in cocoons on the ground. Pupation occurs in the spring, and adults

of the first generation appear in late May or June. Larvae of this generation are found in June and July. Adults of a second generation appear from late July to early September. This species is often abundant locally in the Northeastern States.

Approximately 40 additional species in the genus *Nematus* have been recorded from eastern forests. Known hosts of a few species are as follows: black locust—*N. abbotii* (Kirby); black locust and honey locust—*N. tibialis* Newman; paper birch—*N. viridescens* Cameron and *N. pinguidorsum* Dyar; willow and possibly poplar—*N. fulvicrus* Provancher; poplar—*N. hudsoniimagnus* Dyar; hophornbeam—*N. ostryae* (Marlatt); American hornbeam—*N. carpini* (Marlatt); alder—*N. erythrogaster* Norton; poplar and willow—*N. limbatus* Cresson; and willow—*N. oligospilus* Foerster.

Trichiocampus viminalis (Fallén), the **poplar sawfly**, an introduced species, occurs across southern Canada and the Northern United States. Its hosts are various species of poplar and sometimes willow. Full-grown larvae are orange-yellow, sparsely clothed with yellow hairs, and about 18 mm long. Each side of the body is marked with two rows of more or less rounded black spots. Those of the lowest row are small (fig. 195).



Courtesy Conn. Agric. Exp. Stn.

Figure 195.—Larvae of the poplar sawfly, *Trichiocampus viminalis*, on leaves of poplar.

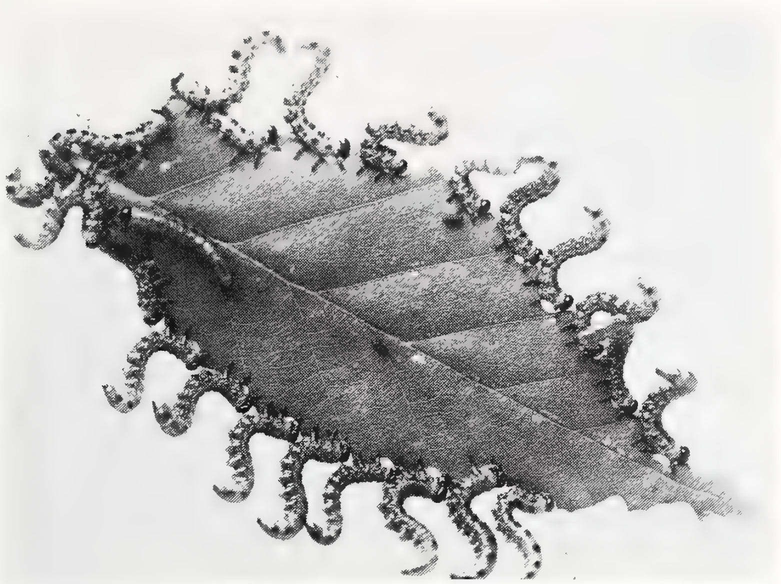
Winter is spent in the prepupal stage in cocoons in the duff beneath the trees. Pupation occurs in the spring and the adults appear in May. Young larvae feed side by side on the leaves.

Older larvae tend to scatter and eat all but the midribs and larger veins. They become full grown in June or early July. Some pupate and give rise to a second generation of adults in August; the remainder do not complete their development until the following spring. Carolina and Lombardy poplars grown for ornamental purposes may be seriously defoliated.

The **dusky birch sawfly**, *Croesus latitarsus* Norton, is the most commonly encountered species in the genus, and occurs in eastern Canada and south through the Eastern States to Florida and west to Alaska, British Columbia, and Utah *(1098)*. Its hosts are various species of birch, preferably gray birch. Full-grown larvae are yellowish green with shades of black and are about 24 mm long. There is a row of more or less distinct black blotches on each side and a series of black spots in the subspiracular area.

Winter is spent in the prepupal stage in a cocoon in the topsoil. Adults appear during May and June, or earlier in the Deep South. There may be several overlapping generations per year and larvae may be found from spring until fall. The larvae are gregarious and feed along the edges of the leaf (fig. 196). Colonies are often found defoliating small saplings, but this usually does not occur over wide areas.

Other species of *Croesus* include *C. curvarius* Smith on hazel, *C. castaneae* Rohwer on chestnut, and *C. varus* (Villaret) on alder, the latter sawfly of foreign origin.



Courtesy Conn. Agric. Exp. Stn.

Figure 196.—Larvae of the dusky birch sawfly, *Croesus latitarsus*.

The **striped alder sawfly**, *Hemichroa crocea* (Geoffroy), probably an introduced species, occurs from coast to coast in southern Canada and the Northern United States south to New Mexico. Its hosts include various species of alder and occasionally birch, hornbeam, and willow *(1101)*. Full-grown larvae are yellowish and about 20 mm long. The head is shiny black, and there is a dark-brown subdorsal stripe on each side running from the second thoracic to the tenth abdominal segment. Two broken subspiracular stripes composed of blotches and dashes extend along each side to the ninth segment.

Winter is spent in the prepupal stage in cocoons just beneath the surface of the soil. The cocoon is very thin-walled and is formed within a cell made by cementing together particles of soil. Adults appear during late May and deposit their eggs in slits cut in the sides of the midrib on the undersurface of leaves. The larvae are gregarious and usually eat all but the midrib and larger veins of the leaf. They become full grown in July, and adults of a second generation appear during late July and August. Larvae of this generation are found during August and September. There are two generations per year. This species occasionally severely defoliates alder in the Lake States, Northeastern States, and Canada.

The **maple petiole borer**, *Caulocampus acericaulis* (MacGillivray), is known to occur in Ontario, Connecticut, New York, Maryland, Michigan, Illinois, and Alabama. The larvae feed by boring into and tunneling the petioles of maple leaves. Full-grown larvae are light yellow with light-brown heads and are about 8 mm long.

Winter is spent in the prepupal stage in a cell 5.0 to 7.5 cm below the surface of the soil. Adults appear early in May and deposit their eggs near the bases of the

petioles of maple leaves. The larvae tunnel in the petioles, usually breaking them near the leaf blade, and the leaves fall (fig. 197). After the petioles break, the larvae continue to feed for about 1 week to 10 days in those portions of the petioles remaining on the tree. When these also break and fall, the larvae vacate them and enter the soil to pupate. There is one generation per year.

Courtesy Conn. Agric. Exp. Stn.

Figure 197.—Petiole of maple leaf severed by larvae of the maple petiole borer, *Caulocampus acericaulis*.

Damage by the maple petiole borer is slight. Nevertheless, heavy infestations on valuable shade trees may be undesirable because of the presence of large numbers of dead leaves during the summer.

The **brownheaded ash sawfly**, *Tomostethus multicinctus* (Rohwer), occurs in southern Canada and throughout the Eastern United States west to the Great Plains, and also in Oregon and California. Its hosts are red and white ash trees. Full-grown larvae are greenish or yellowish white and from 14 to 20 mm long.

Winter is spent in the prepupal stage in cocoonlike cells in the topsoil. Adults appear as early as April in the southern portions of its range and lay their eggs in slits cut along the outer margin of young leaflets, several eggs per leaflet. Young larvae chew holes in the leaflets, and the older ones consume them entirely. Larvae become full grown and move to and enter the ground by late May in the South. Farther north, they become full grown at progressively later dates. Pupation occurs in the spring and there is only one generation per year. The larvae are such voracious feeders that a heavily infested tree may be completely defoliated in 1 week. Shade trees are especially subject to serious defoliation *(713)*.

The **blackheaded ash sawfly**, *Tethida cordigera* (Palisot de Beauvois), occurs throughout much the same area as the brownheaded ash sawfly, except Oregon and California. The habits, food plants, and life histories of the two species are also very similar. Full-grown larvae are whitish with a yellowish tinge and are about 18 mm long. The head is shiny black, and the thoracic legs are blackish brown. This species is occasionally a pest of shade trees.

Eriocampa juglandis (Fitch), the **butternut woollyworm**, occurs from New Brunswick to North Carolina west to Ontario, Minnesota, and Nebraska. Its hosts are butternut, black walnut, and hickory. Full-grown larvae are green, with indistinct black spots on the sides, and are about 18 mm long. The body is covered with flocculent white tufts that rub off when touched, and the head is white with black eyes. Larvae feed gregariously, often causing considerable defoliation locally. When they become full grown they move to and enter the ground, where they form cocoons made of soil cemented together. Winter is spent in the cocoons and there is one generation per year.

The genus *Hoplocampa* is represented in eastern America by a number of species, all of which presumably feed as larvae in the fruit of their hosts. Eggs are laid in the calyx of flowers and the larvae bore into and hollow out the developing fruit. Some of the species and their known hosts are: *H. oskina* Ross—hawthorn from Maine, New York west to Michigan, Iowa and Kansas; *H. halcyon* (Norton)—serviceberry from Maine to North Carolina west to Alberta and Illinois; *H. pallipes* MacGillivray—serviceberry from New Hampshire, New York to Michigan, Alberta, British Columbia, Oregon, and California; *H. lacteipennis* Rohwer—chokecherry in southeastern Canada and from Maine to New York, west to Manitoba, Alberta, Montana, and Colorado; and *H. montanicola* Rohwer—chokecherry in the Northern United States and southern Canada.

The genus *Anoplonyx* contains four species that occur in the Northern United States and Canada. The larvae of all species feed on various species of larch. Full-grown larvae of the two eastern species, *A. canadensis* Harrington, the **onelined larch sawfly**, and *A. luteipes* (Cresson), the **threelined larch sawfly**, are green and range in length from about 9 to 15 mm. The thorax is larger than the abdomen, producing a humpbacked appearance and causing the body to taper posteriorly *(144)*.

The genus *Euura* is represented in the Eastern United States and Canada by 10 species, and all are gall-makers on various species of willow. Larvae are usually yellowish or greenish white with black eyes, and the head is often tinted brown. All species apparently have one generation per year. Winter is spent as prepupae either in cocoons in the ground or in galls on the host. Adults appear in the spring and lay their eggs in the shoots. Larvae feed on the tissues and become enveloped in galls on stems, twigs, petioles, or buds.

Pontania spp. form leaf galls on willow, while *Phyllocolpa* spp. live in rolled leaves or rolled leaf edges.

The genus *Macremphytus* is represented in eastern forests by three species, all of which feed as larvae on dogwood. Full-grown larvae of some species are creamy yellow on top with grayish-black crossbands or spots, and the legs and venter are yellowish. The head is shiny black, and the body is covered with a white powdery secretion.

Superfamily Siricoidea—Family Siricidae
Horntails

Members of the family Siricidae are commonly known as horntails because of the presence of a hornlike projection on the last abdominal segment of the adult. This process is short in the male; in the female it is much longer and often spear-shaped. The ovipositor of the female is long and fitted for boring. In this respect it differs from the ovipositor of sawflies that consists of sawlike plates. Horntails attack both hardwoods and coniferous trees. A few species have been recorded infesting vigorous trees, but they usually prefer trees or parts of trees that are dead or in a

badly weakened condition. Horntail larvae are parasitized by several members of the ichneumonid genera *Rhyssa* and *Megarhyssa*. Members of the latter genus are of special interest because of their striking appearance. Using their extremely long ovipositors, the females bore deep holes into the wood and deposit their eggs on or near horntail larvae in their galleries. The ovipositor often becomes caught in the wood and the female, unable to escape, dies. *M. atrata* (F.), *M. macrurus macrurus* (L.), and *M. greenei* Viereck are parasites of *Tremex columba* (L.), but not of any other horntails.

Horntail adults are medium to large in size and are usually metallic blue or black. Some are varicolored with combinations of black, red, and yellow. The head, thorax, and abdomen are of equal width; the wings are well developed; the antennae are long and filiform, with about 15 segments; and the anterior tibia is armed with a single apical spur, cleft at the apex.

Damage caused by members of the family can be prevented or reduced by promptly using infested logs or submersing them in water, and by kiln-drying green lumber sawed from infested logs.

The genus *Sirex* is represented by four eastern species. *S. juvencus* (L.) occurs in eastern Canada and the Northeastern and Midwestern States. Its hosts are listed as pine, fir, and spruce. Canadian studies indicate that *S. juvencus* larvae do not develop in the absence of the fungus, *Stereum chailletii* (Pers.) Fr. *(1159)*. In New Brunswick, the males precede the earliest females by 2 to 4 weeks, before each of the sexes continues emerging sporadically throughout the summer. Peak emergence continues for a month from mid-August. Oviposition begins within a day of emergence; a 2- to 10-mm puncture into the sapwood is completed in about 8 to 10 minutes. One to three eggs are deposited at intervals along the oviposition site. Eggs or early-stage larvae overwinter. Pupation occurs after 5 to 11 molts, and the pupal stage lasts 4 to 6 weeks. It takes 2 to 3 years for *S. juvencus* to complete its life cycle *(1159)*. The **blue horntail**, *S. cyaneus* F., attacks spruce, larch, and pine in southern Canada and the northern tier of Eastern States. *S. edwardsii* Brulle has been taken from pitch pine in the Atlantic Coast States and is recorded from Quebec to Georgia west to Saskatchewan, Wisconsin, and Arkansas. *S. nigricornis* F. has been recorded from shortleaf, eastern white, and Virginia pines and is distributed from Quebec to Florida west to Saskatchewan, Wisconsin, Arkansas, and Louisiana.

Sirex areolatus (Cresson) has been introduced from western North America into the Southeastern United States, but may not have become established.

The genus *Urocerus* Fourcroy is represented by four eastern species. *U. albicornis* (F.), the **whitehorned horntail**, attacks many species of conifers and occurs throughout boreal America. Adults are blue-black or black and about 25 to 30 mm long. The middle of the antennae, cheeks, bases of the tibiae, and tarsi are white. White spots also occur at times on the sides of the abdomen. This species has also been observed attacking freshly sawed lumber. *U. gigas flavicornis* (F.), the **yellowhorned horntail**, attacks spruce and other conifers in New England and Canada. Adults are black and from 20 to 37 mm long. Females have the first, sixth, and part of the seventh abdominal segments yellow; males have the second through fifth segments orange-yellow. The fungus, *Stereum chailletii*, is also associated with this siricid *(1159)*. *U. cressoni* Norton, the **black and red horntail**, occurs from eastern Canada to Florida, west to Wisconsin and Minnesota, and breeds in fir, spruce, and pine. *U. taxodii* (Ashmead) infests baldcypress in Florida.

The **pigeon tremex**, *Tremex columba* (L.), is the most common of the horntails.

It occurs throughout eastern North America and breeds in a wide variety of dead or weakened deciduous trees such as beech, maple, birch, elm, hickory, oak, and sycamore. The adult female is 37 to 50 mm long. The head, antennae, and thorax are reddish and black; the abdomen is black with ocher-yellow bands and spots along the sides; and the wings are smoky brown with a wingspread of 50 mm or more. Males are reddish, with some black, and are about 18 to 37 mm long. Full-grown larvae are whitish, cylindrical, and about 50 mm long. The abdomen ends in a short, strongly sclerotized and compressed process armed with two pairs of small teeth.

The female bores through the bark into the wood to a depth of about 12 mm to deposit her eggs. Although laid singly, several eggs may be found near each other in a limited area. The fungus, *Daedalea unicolor* Bull. ex Fr., is essential for larval development *(1160)*. The larvae feed by excavating tunnels entirely in the wood. This frequently weakens the tree and leads to windbreakage. Pupation occurs at the end of the larval tunnel and the adults emerge through circular holes about 8 mm in diameter. There appears to be one generation per year, although in New Brunswick, it has a minimum of a 2-year life cycle *(1160)*.

Eriotremex formosanus (Matsumura), the **Formosan horntail**, a species probably introduced from Taiwan or Indochina, has been collected from dead water oak and hardwood logs in Alabama and has been reported from Florida and Georgia. Female adults are black with yellow hairs on the head and body, yellow pronotum, yellow bands and spots on the abdomen, and yellowish to reddish-brown wings with the area around the stigmata of the forewings and apical margin of each wing infuscated. *E. formosanus* probably prefers dead, dying, or weakened hardwood tress and may be similar in habits to *Tremex columba (1100)*.

Family Xiphydriidae
Xiphydriids

The family Xiphydriidae is represented in the United States and Canada by eight species, all of which occur in the Eastern United States. One species occurs west to the Northwest Territories, British Columbia, and Oregon. The adults are somewhat similar to those of the family Siricidae, but are only about 12 to 18 mm long, and the female ovipositor sheath is seldom longer than the last tergite. Adults are reddish, black and yellowish, or entirely black. Full-grown larvae are about 18 mm long and the abdomen ends with a brown concave prong ornamented with teeth on the underside. As a rule, the larvae feed in moderately sound to partly decayed wood of deciduous trees, usually in small branches. Adults sometimes emerge from firewood brought inside, but they are no threat to people or property *(1102)*. Few, if any, are ever very abundant.

Eastern species and their known hosts and distribution are as follows: *Xiphydria abdominalis* Say—basswood from southern Canada to North Carolina, Wisconsin, and Iowa; *X. maculata* Say—maple in Canada and most of the Eastern United States except the Gulf States; *X. tibialis* Say—elm, birch, beech, American hornbeam, oak, and hawthorn in southeastern Canada from Nova Scotia, Quebec, south to Florida and west to Wisconsin, Illinois, and Kansas; *X. hicoriae* Rohwer—hickory and elm in southeastern Canada and from Massachusetts and New Jersey to Illinois; *X. mellipes* Harris—birch from Nova Scotia to North Carolina west to the Northwest Territories, British Columbia, and Oregon.

Family Orussidae
Orussids

Five species of the family Orussidae have been recorded from the United States and Canada, three of which occur in the Eastern United States. The adults are

somewhat similar to those of the Siricidae, but are much smaller, ranging from only about 8 to 14 mm in length. As far as known, the larvae are all parasitic on woodborers.

Superfamily Cephoidea—Family Cephidae
Stem Sawflies

The larvae of all members of this family and superfamily are borers in the stems of plants such as grasses or berries, or in the tender shoots of trees and shrubs. Only 12 species are recorded from the United States and Canada. Adults are slender-bodied and seldom more than 18 mm long. The body is black or dark colored, occasionally marked with narrow yellow bands. The antennae are filiform, with 20 to 30 segments, and are either spindle-shaped or club-shaped. The front tibia has a single apical spur, cleft at the apex.

The **willow shoot sawfly**, *Janus abbreviatus* (Say), occurs in southern Canada west to Manitoba and South Dakota, and over much of Eastern United States *(1136)*. Its hosts are willow and poplar. Full-grown larvae are white, cylindrical, and about 12 mm long. The thoracic legs are indistinctly jointed and fleshy. There is a single pair of small prolegs on the last abdominal segment and a short, tubular prong on the tip of the abdomen. Adults appear in late May and June and the females deposit their eggs in punctures in the shoots of their hosts. Sometimes they girdle and weaken the shoots above the oviposition site. The larvae feed by boring down through the pith, which kills the shoot for varying distances. Winter is spent within the shoot in cocoonlike structures. There is one generation in the North, and three generations in Mississippi *(1136)*.

Suborder Apocrita

Members of the suborder Apocrita have the base of the abdomen constricted into a slender petiole or "waist." The constricted portion is the first abdominal segment, which is fused to the thorax. Thus, what appears to be the first segment of the abdomen is actually the second. The adult female is equipped with a piercing ovipositor. In some species it is used as a tool for boring deep holes into the wood in which eggs are deposited; other species use it for thrusting eggs into the bodies of other insects; in still others, it is connected to poison glands and is used as a sting. The larvae are usually grublike or maggotlike. Some feed as parasites or predators on other insects and some feed on plants. Adults feed chiefly on flowers, sap, or other plant materials; some parasitic species feed occasionally on body fluids of the host.

Considered as a whole, members of this suborder are far more beneficial than harmful. Only a few species are harmful to trees or wood products. A number of species are injurious to tree seed and cone crops. Some species of ants are destructive to young trees in nurseries, plantations, and natural regeneration areas, whereas others are destructive to finished wood products. At present, there are approximately 15 times more species in this suborder than in the Symphyta.

Superfamily Ichneumonoidea

This superfamily constitutes one of the largest groups of parasitic insects (more than 5,000 species) and from the point of view of effectiveness in holding in check the numerous pests that infest plants, it probably ranks first *(216)*. It comprises five families (Stephanidae, Aphidiidae, Braconidae, Hybrizontidae, and Ichneumonidae), containing more than 30 subfamilies, hundreds of genera, and thousands of species *(697)*. Only a small portion of the important species parasitic on

forest insects is mentioned. A complete list of the species known to occur in the United States and Canada is available *(697)*.

Family Stephanidae
Stephanids

This small family of rather rare insects, parasitic on coleopterous and hymenopterous wood borers, is represented in eastern forests by only one genus and two species. Adults are usually collected on dead trees harboring their wood-boring hosts. The adult is odd looking, having a crown of teeth on its spherical head which is situated at the end of a long neck.

Family Aphidiidae
Aphidiids

Until recently this family was considered a subfamily of the Braconidae. It consists of 3 subfamilies, some 16 genera, and 114 species. Most species are solitary endoparasites of both larval and adult aphids. Pupation may take place inside or outside the mummified host. Several species have been introduced from abroad in biological control programs *(697)*.

Family Hybrizontidae
Hybrizontids

This small family, consisting of one genus and two species, was originally considered a subfamily of the Braconidae. Because of their rarity, little is known of their host relationships. They may be parasites of ants or aphids *(697)*.

Family Braconidae
Braconids

The family Braconidae constitutes one of the major groups of insect parasites. The majority of species, nearly 2,000 for North America, are parasitic in the larvae of Lepidoptera, but a large number are also parasitic in the larvae of several other orders, especially the Coleoptera. Braconid adults are seldom more than 15 mm long. They resemble those of the family Ichneumonidae in lacking a costal cell but differ in not having more than one recurrent vein. Many species pupate in silken cocoons on the outside of the body of the host, whereas others spin cocoons entirely apart from their hosts. There are from one to many generations per year, depending on the species. In some species the life cycle may be completed in less than 2 weeks *(216)*.

In addition to the large number of native species attacking forest insects, several species have been imported from abroad to parasitize important introduced pests. Following is a brief description of a few of these.

Agathis pumila (Ratzeburg) was imported into the United States and Canada against the larch casebearer during the 1930's. It is now widely distributed throughout eastern Canada and the Northeastern United States and is providing a high degree of suppression in some areas. It has also been transferred from the Northeast into Idaho where the larch casebearer was first discovered on western larch in 1957. Genetic stock of *A. pumila* from Wisconsin was also released and established in Oregon and Washington in 1973 and 1974 *(1047)*. Winter is spent in the larval stage within the host and there is one generation per year.

Meteorus versicolor (Wesmael), a parasite of the browntail moth and various other species of Lepidoptera, was introduced from Europe into the United States early in the century, and is known to have been established since 1909. It is now widely distributed throughout the range of the browntail moth in New England, but appears to be of little value in its suppression. Attempts to establish it on the satin moth in the Northeast have failed. It is established on the satin moth in the Pacific Northwest, however, where it is considered an important control factor *(218, 328)*.

Dolichogenidea (= Apanteles) lacteicolor Viereck *(825)*, a parasite of the browntail moth in Europe, was introduced in 1907, established in the United States by 1908, and is now generally distributed throughout the range of its host. Studies made several years after its establishment showed a rate of parasitization less than 10 percent of overwintering larvae over a wide area *(218)*. Winter is spent within young browntail moth larvae. The adults appear in the spring, and two generations may develop utilizing alternate hosts *(173, 894)*.

Cotesia (= Apanteles) melanoscelus (Ratzeburg) *(825)*, a European parasite of the gypsy moth, was introduced to New England in 1911 and 1912 and became established quickly. Later, it was recolonized widely and is now generally established over the infested area of New England. Parasitization is sometimes high in localized areas in the Northeast. Its abundance is greatly reduced in the spring by hyperparasites that attack overwintered cocoons. Under the name *Apanteles solitarius* (Ratzeburg), this parasite was released in New England against the satin moth in 1927. Parasitization as high as 67 percent has been recorded. The winter is spent either as a first instar in a satin moth larva or as a prepupa in a satin moth cocoon. Thus, two separate broods of adults arise from the overwintering generation, each of which produces a second generation during the summer *(957)*.

Phanomeris phyllotomae Muesebeck was imported from Austria to New England and New York in the early 1930's against the birch leaf-mining sawfly. It became established but its effectiveness in suppression has not been determined. There is one generation a year *(327)*.

Orgilus obscurator (Nees) was imported by the United States and Canada in the 1930's against the European pine shoot moth and is now widely distributed in most shoot moth infested areas. Parasitization is variable, and in the United States, has ranged from very low to as high as 50 percent. Significant levels of parasitization have also been recorded in parts of Canada. Winter is spent as a first or second instar within the hibernating host larva and there is one generation per year.

Family Ichneumonidae
Ichneumons

There are more than 3,000 described species of ichneumons in the United States and Canada, and probably at least 5,000 undescribed ones *(1208)*. The family has been divided into 27 subfamilies and 502 genera *(697)*. All members of the family are parasites of the larvae and pupae of holometablous insects, or of spiders, spider egg sacs, or pseudoscorpions. The majority of insect hosts belong to the order Lepidoptera, but many species of Hymenoptera, especially the sawflies, and a considerable number of Coleoptera are attacked.

Ichneumon adults vary greatly in size, form, and coloration. They resemble slender stinging wasps, but differ in having the antennae longer and with more segments, in having the trochanter two-segmented, in having the ovipositor permanently extended, and in lacking a costal cell in the front wing. They also resemble adult braconids but differ in having two recurrent veins in the forewing instead of just one.

Forest and shade tree insects are parasitized by a great many species of ichneumons, far too many to mention here *(697)*. The majority are native to this continent and attack native hosts. In addition to these, a number of species have been introduced from abroad against several important introduced hosts *(328)*.

Pleolophus basizonus (Gravenhorst), a European parasite of sawfly cocoons, was introduced originally to Canada against the European spruce sawfly during the 1930's, and several colonies were made available for liberation in the United States

against both the European spruce sawfly and the European pine sawfly. It became established on the European pine sawfly, which it parasitizes heavily at times. *P. basizonus* also has been reared from cocoons of the introduced pine sawfly in North Carolina and from *Neodiprion pratti paradoxicus* in New Jersey *(328)*. It has not been recovered from the European spruce sawfly in the United States.

Exenterus amictorius (Panzer), a parasite of the European pine sawfly in Europe, was imported to Canada during the 1930's against the European spruce sawfly and European pine sawfly. Colonies were later made available for release in the United States. It is an important parasite of the introduced pine sawfly in Wisconsin and North Carolina, and has been recovered from several *Neodiprion* species including *N. sertifer, N. lecontei, N. nanulus nanulus*, and *N. swainei (697)*.

Mesoleius tenthredinis Morley was imported to Canada from England in 1910 and 1911 and liberated against the larch sawfly in Ontario, Canada. A small colony was also released against the sawfly in Michigan. It became established and for many years effected considerable suppression. Gradually though, the host developed an immunity to the parasite in many portions of its range, thereby greatly reducing its effectiveness. A Bavarian strain of *M. tenthredinis* is showing considerable promise in Canada *(1216)*. *Olesicampe benefactor* Hinz was introduced from Europe to Canada to supplant *M. tenthredinis* in suppression attempts against the larch sawfly. It is doing this very well in the Prairie Provinces and is established in Minnesota *(629, 704, 896)*, and a recent release seems promising in Pennsylvania *(341)*.

Coccygomimus turionellae turionellae (L.), a European parasite of the pupae of many Lepidoptera, was imported against the European pine shoot moth during the 1930's without success. Releases have been made against other lepidopterans, and though it has not been recovered in the United States, it is apparently established in southern Ontario *(697)*.

Temelucha interruptor (Gravenhorst) was imported from England and Europe against the European pine shoot moth during the 1930's. It became established and was recovered in Connecticut, New Jersey, and southern New York in 1937. Ten years later, however, it had almost disappeared, being collected at only one point in Connecticut. This species is cleptoparasitic on *Orgilus obscurator* and thus is detrimental to the biological control program against the European pine shoot moth *(697)*.

Eastern forest insects also are attacked by numerous native species of ichneumonid parasites. *Itoplectis conquisitor* (Say) parasitizes a tremendous number of species, and is especially important. *I. quadricingulata* (Provancher) and *I. viduata* (Gravenhorst) also attack a great many species. *Megarhyssa macrurus* (L.) is a conspicuous parasite of the pigeon tremex.

Superfamily Chalcidoidea
Chalcids

This superfamily contains more species than any other superfamily in the order Hymenoptera. It contains, among its families, probably a majority of all entomophagous insects, with an extremely wide range in form, habits, host preferences, and host relationships. The entomophagous species make up the majority and are mostly beneficial, but there also are a number of phytophagous species, many of which are economic pests. The species occurring in the United States and Canada originally were divided into 21 families and more than 460 genera *(974)*; however, current researchers divide the superfamily into 11 families, 490 genera, and more than 2,000 species *(697)*.

Practically all of the more common orders of insects serve as hosts for the parasitic and predacious members of the Chalcidoidea, with the Lepidoptera, Diptera, Coleoptera, and Homoptera being preferred. The majority of the injurious tree-infesting species in this country are those that destroy the seeds of their hosts.

Chalcids are mostly small to minute in size—some are less than 0.25 mm in length. The antenna is elbowed, the pronotum does not extend back to the tegula, the trochanter is two-jointed, the forewing is without either a stigma or closed cells, the ovipositor issues some distance before the apex of the abdomen, and a prepectus is present *(697)*.

Family Mymaridae
Mymarids

This family, closely related to the Eulophidae, is represented by more than 100 species in the United States and Canada, the majority of which occur in the East. All members of the family are internal parasites in the eggs of other insects, particularly of Homoptera. Adults are mostly black or yellow and are extremely minute, usually less than 1 mm long.

Polynema striaticorne Girault is an important parasite of several species of membracids. It also attacks various aphids and other insects. Its bionomics in Ohio and Illinois have been studied *(52)*. *Acmopolynema bifasciatipenne* (Girault) parasitizes the eggs of several species of tree crickets. *Ooctonus aphrophorae* Milliron attacks the Saratoga spittlebug *(697)*.

Family Trichogrammatidae
Minute Egg Parasites

The family Trichogrammatidae, with some 43 species, consists of extremely small insects all of which are internal parasites in the eggs of other insects *(15, 697)*. Hosts have been recorded from the orders Lepidoptera, Coleoptera, Hymenoptera, Neuroptera, Diptera, and Hemiptera, but the Lepidoptera are preferred.

Trichogramma minutum Riley parasitizes the eggs of a great many species of insects, including many important enemies of trees. The following is a partial list of important eastern hosts: locust leafminer, gypsy moth, browntail moth, orangestriped oakworm, saddled prominent, walnut caterpillar, satin moth, hickory shuckworm, European pine shoot moth, Nantucket pine tip moth, forest tent caterpillar, spruce budworm (as many as 75 percent of spruce budworm eggs may be attacked), eastern blackheaded budworm, bagworm, elm sawfly, fall webworm, yellowheaded spruce sawfly, and fall cankerworm *(974)*.

The adult is less than 0.5 mm long, and females insert their eggs directly into host eggs in arboreal habitats. During warm weather, the life cycle may be completed within 9 to 16 days and there may be 12 or more generations per year.

Family Eulophidae
Eulophids

Adults of this family are very small, ranging in length from 1 to 3 mm. Well over 100 species are known to parasitize tree-infesting insects, several of which are important pests *(974)*. A number of foreign species have been imported to the United States and Canada in efforts to suppress several species of introduced pests. The family contains more than 500 North American species *(697)*.

Chrysocharis laricinellae (Ratzeburg) (fig. 198), a parasite of the larch casebearer and the birch leafminer, was introduced from Europe to New England and Canada in the late 1920's and 1930's. It is now widely established. Adults are bright metallic-green with pale-yellow legs, and are about 2 to 3 mm long. There may be three generations per year in the casebearer, but there is only one and a partial

second in the leafminer. *C. laricinellae* was reported ineffective against the casebearer because it acted as a secondary parasite, attacking the more effective *Agathis pumila (327)*. Recent studies indicate it can be effective, especially in concert with *A. pumila*, as a successful multiple parasite. The species has been transferred to the Northwest where it is established on the larch casebearer *(1047)*.

F-519579

Figure 198.—Adult of the parasite *Chrysocharis laricinellae*.

Dahlbominus fuscipennis (Zetterstedt), a parasite of several species of sawflies in Europe, was introduced to Canada in 1934 for release against the European spruce sawfly. The following year, shipments were received from Canada for release against the same species in Maine. Since then, releases have been made against several other sawflies in Canada and the United States. So far, it has been recovered in this country from the European spruce sawfly in New England, the European pine sawfly in New Jersey, the redheaded pine sawfly in Michigan, the Virginia pine sawfly in Virginia, *Neodiprion pratti paradoxicus* Ross and *N. pinusrigidae* (Norton) in New Jersey, the red pine sawfly and the introduced pine sawfly in Wisconsin and North Carolina, the balsam fir sawfly in Maine, *Gilpinia frutetorum* (F.) in Connecticut, and others *(328, 697)*.

Adults are 2.3 to 2.8 mm long. The head, thorax, and abdomen are black; the wings have a smoky tinge; the legs are white to light brown, except the femur which is black; and the antennae are elbowed and black, except for a white scape in the female. This species is an external parasite of sawfly larvae and of pupae within their cocoons. There are from two to seven generations per year, depending on location. It has never become a very effective parasite of the spruce sawfly. Yet, almost 50 percent parasitization of the European pine sawfly has been recorded locally in New Jersey.

The genus *Tetrastichus* contains a large number of parasites of important forest insect pests. Descriptions of most North American species and information on their distribution and hosts have been published *(15, 175)*.

Tetrastichus turionum (Hartig) was imported from Europe during the 1930's and released in New England, New York, and New Jersey against the European pine shoot moth. Several years later it was also released in Ontario. It occurs in Massachusetts, New Jersey, Connecticut, on Long Island, N.Y., and in southern Ontario. The adult is a tiny, iridescent, blue-green insect. The antennae are brown and the apices of the femora and the tarsi are light yellow or white. This is a pupal parasite and it has one generation per year. So far, it has been of no consequence in suppression of the shoot moth in this country.

Tetrastichus brevistigma Gahan is a pupal parasite of the elm leaf beetle. Adults are black with a slight metallic-green tinge and are only about 0.5 to 1.5 mm long. An average of 12 parasite larvae develop in each pupa and there are three or four generations per year. Parasitization as high as 50 to 80 percent occurs commonly in the vicinity of Boston, Mass., where it was introduced from California. *T. holbeini* Girault and *T. rugglesi* Rohwer attack several species of *Chrysobothris* and *Agrilus*, respectively.

Dimmockia incongrua (Ashmead) parasitizes the gypsy moth and many other species of Lepidoptera, although it is almost always a secondary parasite *(697)*. *Elachertus cacoeciae* Howard parasitizes various species of Lepidoptera. Members of the genus *Hyssopus* parasitize several species of shoot and tip moths and seed- and cone-infesting insects.

Family Encyrtidae
Encyrtids

This is a large family of parasites. Insect hosts are widely distributed among the various orders, but the majority of species are parasitic on aphids, scales, and whiteflies. Adults are 1 to 2 mm long.

Coccophagus insidiator (Dalman), a European parasite of the introduced European elm scale, was discovered at Ithaca, N.Y., in 1924, where it was parasitizing the scale quite heavily. It had apparently been introduced to the area by accident. The female is an endoparasite of the scale; the male an ectoparasite of the larval stage of the female parasite. There may be three to five generations per year.

Ooencyrtus kuvanae (Howard), a parasite of gypsy moth eggs, was introduced to the United States in 1908 and 1909 from Japan *(15, 267)*. The adult is black and about 1 mm long. Winter is spent in the adult stage, during which mortality may be severe.

Surviving adults appear during April and lay their eggs in the overwintered eggs of the host. There may be one or two spring generations; for the entire year there may be four or five generations. This species is an important parasite of the gypsy moth in the southern portion of its range. Parasitization of 40 to 50 percent frequently occurs in Massachusetts and Connecticut. *O. ennomophagus* Yoshimoto (fig. 199), a parthenogenetic member of this family, was responsible for the suppression of the elm spanworm in Connecticut in the early 1970's *(15)*. It develops only in unembryonated eggs of its hosts *(653)*. *O. trinidadensis* Crawford parasitizes eggs of the leaffooted pine seed bug and of the shieldbacked pine seed bug, both pests of loblolly pine cones and seed.

F-531262

Figure 199.—*Ooencyrtus ennomophagus* parasitizing eggs of *Eutrapela clemataria*, the purplish-brown looper.

Habrolepis dalmanni (Westwood) is sometimes fairly common as a parasite of the golden oak and oystershell scales in this country. It has been introduced to New Zealand from New England and is credited with having saved the oaks in that country. *Kermes pubescens* Bogue, another oak scale, is attacked by at least five other species of encyrtids. The European fruit lecanium is attacked by more than 20 different species. The San Jose scale and oystershell scale are also attacked by several species.

Family Eupelmidae
Eupelmids

Members of the family Eupelmidae parasitize a wide range of insects including Coleoptera, Orthoptera, Diptera, Lepidoptera, Hymenoptera, Hemiptera, and Homoptera. Many other species are hyperparasitic and a few are phytophagous.

Anastatus disparis Ruschka, an egg parasite of the gypsy moth in Europe and Japan, was introduced to New England in 1906, and quickly became established *(15, 267)*. It is now generally distributed throughout the infested parts of New England. Adult females are marked with green and brown, have two broad fuscous bands on the wings, and are 2 to 3 mm long. Males are greenish black with hyaline wings, and are only about 2 mm long. The winter is spent as a mature larva within the gypsy moth egg. Adults appear in June and July and lay their eggs in egg masses of the host. Hatching occurs quickly and larval development is rapid, as the hibernating stage is reached within about 2 weeks. Yet, there is only one generation per year. This species is usually scarce in areas where the egg parasite, *O. kuvanae*, also occurs. Interspecific competition may be the cause. *A. reduvii* (Howard) is an egg parasite of the leaffooted pine seed bug and the shieldbacked pine seed bug.

A few other species of eupelmid parasites and some of their hosts are: *Eupelmella vesicularis* (Retzius)—gypsy moth, satin moth, forest tent caterpillar, European pine shoot moth, and several species of pine sawflies; *Eupelmus cyaniceps* Ashmead—webbing coneworm, Nantucket pine tip moth, bagworm, smaller European elm bark beetle, European pine shoot moth, and bagworm; *E. pini* Taylor—white pine weevil; *E. allynii* (French)—various species of tree crickets; and *Metapelma spectabile* Westwood—buprestid and cerambycid borers.

Family Eucharitidae
Eucharitids

The family Eucharitidae comprises only 6 genera and 28 species. As far as known, all species are parasitic on the pupae of ants. Adults are distinguished by the configuration of the scutellum, which is frequently produced backward in the form of powerful spines *(697)*.

Family Torymidae
Torymids

Most members of this fairly large family (27 genera and 175 North American species) are parasites of gall-forming insects *(697)*. A number of others are parasitic on various lepidopterous larvae; many feed in the seeds of various plants; and some act as hyperparasites.

The genus *Torymus* contains a large number of species that parasitize the immature stages of gall-forming cynipids and gall midges. *T. rugglesi* Milliron has been collected from the seeds of American holly in Delaware.

Members of the genus *Megastigmus* are all phytophagous, developing in the seeds of plants. Eastern species include *M. amelanchieris* Cushman—on serviceberry; *M. laricis* Marcovitch—on larch; and *M. specularis* Walley—on balsam fir. The latter has destroyed up to 40 percent of balsam fir seed during certain years in eastern Canada.

The genus *Monodontomerus* contains several important parasites of various species of Lepidoptera and sawflies. *M. dentipes* (Dalman), a European species which probably entered this country with its European host, the introduced pine sawfly, is now widely distributed in southeastern Canada, in the Northern States from Maine to the Lake States, and in North Carolina. It is not only an effective parasite of the introduced pine sawfly, but also an important parasite of several other sawflies attacking conifers (fig. 200). It spends the winter as a prepupa inside the host cocoon. Adults appear over a fairly long period in the spring and lay their eggs through the host cocoon, depositing several upon the prepupa. There are probably two generations per year in the North.

F-531263

Figure 200.—*Monodontomerus dentipes* ovipositing in a cocoon of the introduced pine sawfly.

Monodontomerus aereus Walker was introduced to New England from 1906 to 1910 against the gypsy and browntail moths. It was released originally as a primary parasite but is much more common as a hyperparasite, attacking both hymenopterous cocoons and tachinid puparia. It is also parasitic on the whitemarked tussock moth and the eastern tent caterpillar.

Other species of *Monodontomerus* recorded as parasites of important forest insects in the Eastern States include *M. indiscretus* Gahan—on birch leafminer; *M. montivagus* Ashmead—on spruce budworm; and *M. minor* (Ratzeburg)—on eastern tent caterpillar, cecropia moth, and spruce budworm.

Family Pteromalidae
Pteromalids

The family Pteromalidae is the largest in the superfamily (129 genera and 395 North American species), and its members act as parasites or hyperparasites of almost all orders of insects *(697)*. The adults are minute, black or metallic-green or bronze insects. Many have a more or less triangular abdomen.

Perilampus hyalinus Say, a common species throughout the United States, may act as a secondary parasite of a large number of insects in which it develops at the expense of many species of primary tachinid and ichneumonid parasites. The adult is a bright metallic bluish green and is from 2 to 4 mm long. The thorax is large and the abdomen triangular. More than 20 species of Orthoptera, 16 species of Lepidoptera, 12 species of sawflies, and many species of ichneumonid, sarcophagid, and tachinid parasites are listed as hosts *(974)*; studies of its biology as a secondary parasite of the fall webworm and as a primary parasite of the Swaine jack pine sawfly have been reported *(1107, 1211)*.

Schizonotus latus (Walker), a primary parasite of the imported willow leaf beetle and several allied species of Chrysomelidae, is widely distributed in the Eastern United States. The larva feeds externally on the pupa of its host. High percentages of parasitization were recorded over a 3-year period in the vicinity of Boston, Mass., but host populations were not materially reduced *(326)*.

Dibrachys cavus (Walker) is a hyperparasite of many primary parasites, but also acts as a primary parasite. It is extremely destructive to many beneficial parasites. In common with the adults of many other parasites, the adults often feed at puncture holes made by their ovipositors. This results in the death of many larvae that are not parasitized.

Family Eurytomidae
Eurytomids

This family contains a number of both phytophagous and entomophagous species. Many form galls in the stems of grasses and other plants; some are parasites of gall-forming Diptera and Hymenoptera; a few are egg parasites of Orthoptera; and others are parasites of various tree-infesting Coleoptera. Adults are usually black and the abdomen is rounded or oval and somewhat compressed.

Eurytoma pissodis Girault is one of the most important parasites of the white pine weevil. The adult is dull black on the thorax, glossy black on its shining abdomen, has conspicuous red eyes, and is from 3 to 6 mm long. Eggs are laid on mature weevil larvae and the winter is spent as a prepupa within the pupal cell of the host. Parasitization of at least 50 percent has been recorded in some white pine weevil infestations.

Species parasitic on other important forest insects include: *E. pini* Bugbee—on European pine shoot moth, Nantucket pine tip moth, pitch pine tip moth, and possibly the introduced pine sawfly; *E. tylodermatis* Ashmead—on hickory shuckworm, European pine shoot moth, and Nantucket pine tip moth; and *E. magdalidis* Ashmead—on southern pine beetle and *Pityophthorus liquidambarus* Blackman.

Family Chalcididae
Chalcids

The family Chalcididae contains many primary and secondary parasites of Lepidoptera, Diptera, Coleoptera, and Orthoptera. The adults of certain species are fairly large and conspicuous; all are solitary in habit and practically all develop inside their hosts.

A few of the more important species and their hosts are: *Haltichella rhyacionia* Gahan—Nantucket pine tip moth, pitch pine tip moth, and a western pine tip moth; *H. xanticles* (Walker)—European pine shoot moth and oak skeletonizer; *Phasgonophora sulcata* Westwood—bronze birch and flatheaded appletree borers; *Trigonura elegans* (Provancher)—several species of woodborers including flatheaded appletree borer, red elm bark and black elm bark weevils; *Spilochalcis albifrons* (Walsh)—numerous hosts including locust and arborvitae leafminers, and larch casebearer; *S. flavopicta* (Cresson)—Nantucket pine tip moth; *S. mariae* (Riley)—bagworm and several species of saturniid moths; *Brachymeria compsilurae* (Crawford)—tachinid flies, especially *Compsilura concinnata* (Meigen) and *Blepharipa pratensis* (Meigen) *(325)*; and *B. ovata* (Say)—a wide variety of lepidopterous hosts including whitemarked tussock moth, hemlock looper, and bagworm.

Superfamily Cynipoidea

The superfamily Cynipoidea consists of very small, dark-colored wasps. Many species are gall makers or gall inquilines. The remainder are parasitic on other insects. This superfamily is divided into six families—Ibaliidae, Liopteridae,

Figitidae, Eucoilidae, Alloxystidae, and Cynipidae *(697)*. The liopterids are mostly exotic, and their habits are unknown.

Family Ibaliidae
Ibaliids

Members of this family are all parasitic on horntails of the family Siricidae. At least four species are recorded from the Eastern United States—*Ibalia anceps* Say, *I. leucospoides ensiger* Norton, *I. maculipennis* Haldeman, and *I. scalpellator* Westwood *(697)*.

Ibalia scalpellator, a common species in the Eastern United States and southeastern Canada, is a parasite of pigeon tremex. The adult is marked with a yellow and dark-brown pattern, has two conspicuous dark-brown to black bands on the forewings, and is about 12 mm long.

Family Figitidae
Figitids

This family of 60 North American species is represented in eastern America by about 30 species. The majority are parasitic in dipterous puparia; a few are parasitic in the cocoons of chrysopids.

Family Cynipidae
Cynipids or Cynipid Gall Wasps

This family of several hundred species consists mostly of species that induce galls on their plant hosts in which they live and feed during the larval stage. Many others live as inquilines in galls produced by other insects. The adults are small to extremely small and usually black. They are distinguished by the abdomen that is oval, shining, somewhat compressed, and almost covered by the first tergite. Many gall-forming species produce two quite different generations per year. One generation develops during the summer in one type of gall. Adults appear in the fall and consist entirely of parthenogenetic females. Eggs laid by these females give rise to larvae that induce an entirely different kind of gall. Adults of this generation consist of both males and females, and may be quite different in appearance from those of the first generation.

It is estimated that 86 percent of the known gall-forming species induce galls on oaks and are confined to them *(668)*. There are 717 species listed as occurring in the United States and Canada, 76 percent of which induce galls on oaks.

The females deposit their eggs in the tissues of all parts of the host, from the roots to the flowers. Gall production is believed to result from the reaction of the cambium and other meristematic tissues to stimuli produced by the larvae. The great majority of species are of little or no economic importance. However, certain species that induce large irregular galls on the smaller branches are capable of causing injury (fig. 201). Infested branches may be disfigured or even killed; occasionally entire trees are killed. On the other hand, galls induced by certain other species are economically valuable—some have long been used in the manufacture of ink and in dyeing and tanning, others serve as a source of winter food for bees. One, a deciduous oak gall, is occasionally abundant enough on black oak in Missouri to be used as food for hogs, cattle, sheep, turkeys, and chickens *(667, 669)*. Some of the more common and important gall-inducing species are discussed below.

Callirhytis floridana (Ashmead) occurs from Virginia to Florida and Missouri and Arkansas. It induces slender, elongate swellings from 12 to 75 mm long on branches close to the ground of Chapman, post, and sand post oaks. Large areas of sand post oaks were nearly all killed during an outbreak in eastern North Carolina *(669)*.

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Figure 201.—Heavy infestation of galls on twigs of Nuttall oak in the Mississippi River Delta region.

Callirhytis quercuspunctata (Bassett), the **gouty oak gall**, occurs from southern Canada to North Carolina and west to Illinois. It induces galls (fig. 202) on the twigs and smaller limbs of scarlet, pin, and black oaks. These galls are about 12 to 38 mm long and they frequently occur so close together that they form practically continuous masses. *C. quercuspunctata* has alternate generations. The first induces small blisterlike galls on the leaves near the veins in the spring. The second induces gouty galls during the summer. In heavy infestations, twigs, fairly large branches, and even entire trees may be killed. Shade trees are especially subject to damage.

Callirhytis cornigera (Osten Sacken), the **horned oak gall**, occurs from southern Canada to Georgia and west to Iowa. It induces galls on the twigs of pin, scrub, black, blackjack, and water oaks. Injurious infestations have been observed on roadside and woodland oaks in the Niagara area of Canada.

Callirhytis quercusgemmaria (Ashmead), the **ribbed bud gall**, occurs from Massachusetts to Florida, and west to Illinois. It induces somewhat conical, strongly ribbed galls about 5 mm long on the twigs of black oaks. These galls sometimes occur in such large numbers as to cause infested twigs to split and die. Entire young trees are sometimes killed.

Callirhytis quercusoperator (Osten Sacken) occurs from New England to North Carolina and west to Iowa. It causes the formation of woolly galls on the staminate flowers of various oaks. When the adults emerge, they oviposit in immature acorns. This results in the formation of so-called acorn pip galls within the acorn cups. In heavy infestations, acorn crops are reduced. *Callirhytis quercusfutilis* (Osten Sacken) induces globose, grayish galls up to 11.4 cm long on the main roots of young white oaks just below the ground line.

Neuroterus quercusbatatus (Fitch), the **oak potato gall** (fig. 203), occurs from Ontario and Rhode Island to Florida and west to Illinois on white oaks. There are two generations per year. Adults of the first generation emerge in May from galls produced on the preceding year's growth. Second-generation adults emerge from green galls. Females of this generation lay their eggs in the same galls from which they emerge.

Neuroterus floccosus (Bassett), the **oak flake gall**, induces small, hemispherical galls from 1.5 to 3.5 mm in diameter on the lower surface of terminal leaves of white oaks. These galls are covered with white hairs and often occur in large numbers on a single leaf. Heavily infested leaves curl and are unsightly on shade trees.

Neuroterus noxiosus (Bassett), the **noxious oak gall**, occurs on swamp white oaks from New England to Virginia and in the Central States. Heavily infested trees may be severely disfigured.

Courtesy Ill. Nat. Hist. Surv.

Figure 202.—Gouty oak galls caused by *Callirhytis quercuspunctata*.

Courtesy Am. Mus. Nat. Hist.

Figure 203.—Oak potato gall on white oak caused by *Neuroterus quercusbatatus*.

Amphibolips confluenta (Harris), the **large oak-apple gall** (fig. 204), occurs from southern Canada to Virginia. It produces galls on the leaves or leaf petioles of various oaks, principally red, black, and scarlet. These galls are large, from 12 to 50 mm in diameter, and greenish to brownish, depending on age. The related species, *A. quercusfuliginosa* (Ashmead), produces globose galls on the sides of the acorn cups of willow and laurel oaks in Florida.

Dryocosmus quercuspalustris (Osten Sacken), the **succulent oak gall**, occurs from southern Canada and New England to Florida and west to Iowa and Louisiana. It induces somewhat circular, succulent galls from 9 to 12 mm in diameter on the leaves or axils of staminate flowers of red oaks. The galls are fleshy walled and hollow, except for a free-rolling cell about 2.5 mm in diameter. *D. kuriphilus* Yasumatsu, native to Japan and Korea, is a pest of Chinese and Japanese chestnuts in Georgia where it was found in 1974 *(967)*.

Xanthoteras quercusforticorne (Walsh), the **oak fig gall**, induces galls on the leaves, twigs, and stems of white oaks in the Eastern States north of Virginia and west to Minnesota. Early in the season they are reddish and bladderlike. Sometimes they occur around a twig in dense clusters up to 8 cm long, and the irregular masses look like pressed figs.

Superfamily Evanioidea—Family Evaniidae
Ensign Wasps

Members of this small family of spiderlike wasps are parasitic in the egg capsules of cockroaches. Adults are about 10 to 15 mm long and are distinguished by very

Courtesy Can. For. Serv., Can. Dep. Environ., Sault Ste. Marie, Ont.

Figure 204.—Large oak-apple gall caused by *Amphibolips confluenta*.

small, oval abdomens attached by petioles to the propodeum considerably above the base of the hind coxae. The majority of described species occur in the Eastern United States.

Family Aulacidae
Aulacid Wasps

The family Aulacidae consists of slender ichneumonlike wasps. The female has an ovipositor about as long as the body. A number of species are parasitic on wood-boring insects; the remainder are parasitic in the nests of bees and wasps in twigs or wood. *Pristaulacus rufitarsis* (Cresson) is a parasite of the hemlock borer and poplar borer in eastern America; *P. bilobatus* (Provancher) is also parasitic on the hemlock borer. *Aulacus burquei* (Provancher), *A. digitalis* Townes, *A. lovei* (Ashmead), and *A. pallipes* Cresson are parasitic on various species of *Xiphydria*.

Superfamily Pelecinoidea—Family Pelecinidae
Pelecinid Wasps

This family appears to be represented in North America by only one species, *Pelecinus polyturator* (Drury), a parasite of June beetle larvae. The female is a large shiny black insect, often up to 62 mm long. The abdomen is slender, about five times as long as the head and thorax combined, and is without a sting. Males are much smaller and have the posterior of the abdomen swollen.

Superfamily Ceraphronoidea—Family Megaspilidae
Megaspilid Wasps

A number of species in this family have been taken from colonies of ants. Most are known to be hyperparasitic primarily on various hymenopterous and dipterous parasites. *Conostigmus virginicus* (Ashmead) is a hyperparasite of *Blepharipa pratensis* (Meigen), an introduced parasite of the gypsy moth.

Superfamily Proctotrupoidea

As far as known, all members of this superfamily are parasitic on the immature stages of other insects. The group as a whole seems to be little known, and most of the North American species are still undescribed. The adults of the majority of species are black, often shiny, and small to extremely small in size. The smaller ones resemble chalcids, but differ in having the pronotum extend laterally to the tegulae and the ovipositor issue from the end of the abdomen. In many of the smaller species, the wings are almost veinless; in others, the wings are entirely absent.

Family Scelionidae
Scelionid Wasps

As far as known, all members of this large family of small insects are parasitic in the eggs of other insects and spiders *(15)*. Species attacking some of the more important forest and shade tree insects are: *Telenomus dalmani* (Ratzeburg)—whitemarked tussock moth; *T. californicus* Ashmead—satin moth and Douglas-fir tussock moth, *Orgyia pseudotsugata* (McDunnough); *T. alsophilae* Viereck—fall cankerworm (fig. 205); *T. bifidus* Riley—fall webworm; *T. catalpae* Muesebeck—catalpa sphinx; *T. droozi* Muesebeck—elm spanworm; *T. coelodasidis* Ashmead—saddled prominent; *Telenomus* sp.—cherry scallop shell moth; and *T. clisiocampae* Riley—forest tent and eastern tent caterpillars. *Gryon pennsylvanicus* (Ashmead) parasitizes eggs of the leaffooted pine seed bug.

Family Platygastridae
Platygastrid Wasps

The majority of species in this family are parasites of Diptera, especially of the families Cecidomyiidae and Tipulidae. A number of others are also important as enemies of mealybugs and whiteflies. The introduced species, *Allotropa burrelli*

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Figure 205.—The parasite *Telenomus alsophilae* ovipositing in eggs of fall cankerworm.

Muesebeck, an important parasite of the Comstock mealybug, has been widely released in the Eastern United States. Two native species, *A. ashmeadi* Muesebeck and *A. convexifrons* Muesebeck, also are important parasites of the Comstock mealybug.

Superfamily Bethyloidea—Family Chrysididae
Cuckoo Wasps

Members of this family are brilliantly metallic blue and green wasps and are popularly known as gold or cuckoo wasps. The majority of species are external parasites of various wasps and bees. A number of species deposit their eggs in the cells of their hosts, and the larvae feed on the original occupants of the cells or on the food prepared for them.

Chrysis shanghaiensis Smith, the only species known to be parasitic upon lepidopterous larvae, was introduced to Massachusetts from Japan in 1917 and 1918 against the oriental moth, also an introduced species. Recoveries were made the year following its release *(956)*, but it has not been recorded since that time.

Subfamily Cleptinae

This subfamily is represented in North America by one genus, *Cleptes*, which is represented by seven species. One of these, *C. semiauratus* (L.), occurs in the East. All parasitize sawflies in their cocoons *(697)*.

Subfamily Amiseginae

Mesitiopterus kahlii Ashmead, *M. floridensis* Krombein, *Microsega bella* Krombein, and *Adelphe anisomorphae* Krombein are egg parasites of walkingsticks.

Family Bethylidae
Bethylid Wasps

Members of the family Bethylidae are parasitic almost exclusively on the larvae of Lepidoptera and Coleoptera. More than 100 species have been recorded from the United States, about two-thirds of which occur in the eastern portion of the country. The adults are small to medium in size. Females are often wingless and antlike and differ so much in appearance from the males that the two sexes are not easily correlated.

A number of species of the genus *Sclerodermus* are often parasitic on larvae of the family Cerambycidae. Additional species of importance as parasites of forest insects and their hosts are *Pseudisobrachium prolongatum* (Provancher)—black carpenter ant; *Parasierola punctaticeps* Kieffer—hickory shuckworm; *Goniozus*

electus Fouts—Nantucket pine tip moth; and *G. longinervis* Fouts—a western pine tip moth.

Family Dryinidae
Dryinid Wasps

This is a small family of rarely collected insects. As far as known, all species are parasitic on the nymphs of Homoptera, especially the membracids, cicadellids, flatids, and cercopids. The females of some genera are wingless and antlike. Also, in most species they differ so much in appearance from the males that the two sexes can be associated only by rearing them.

During the larval stages, these insects are intermediate between ectoparasites and endoparasites in the abdomens of their hosts. Usually one or more external gall-like cysts develop on the integument of the host. These cysts, which may be as large as the abdomen of the host, contain the parasite larvae. The larva absorbs food from the host via the cyst. *Aphelopus theliae* Gahan, a parasite of the membracid, *Thelia bimaculata* (F.), which feeds on young black locust, lays a single egg in a nymph of its host. During oviposition the females secrete a substance that stops host metamorphosis. Polyembryonic development takes place and from 50 to 75 parasites are produced in the nymph. When they reach maturity, they bore through the body wall and drop to the ground to pupate *(461)*.

Superfamily Scolioidea—Family Tiphiidae
Tiphiid Wasps

The family Tiphiidae contains a number of important species parasitic on scarabaeid larvae in soil. As far as known, all species are external parasites, usually feeding on the final instar of the host. The adults of most species are moderate in size, hairy, and black. The remainder are mostly black and yellow. A number of species have been imported against several introduced pests.

Tiphia inornata Say is one of the most common and important parasites of white grubs in the United States. Infestations are heaviest during the years when full-grown white grubs are present. At other times, populations are usually very low *(1348)*.

Tiphia vernalis Rohwer was introduced against the Japanese beetle from Japan and Korea during the period 1924 to 1933. It became established and now plays an important role in control of the beetle in certain parts of the East, especially in Pennsylvania *(217)*. *T. popilliavora* Rohwer, also introduced against the Japanese beetle during the 1920's and 1930's, is now well established from New Hampshire to Virginia and Ohio. *T. asericae* Allen & Jaynes was introduced against the Asiatic garden beetle and *Serica peregrina* Chapin during the 1920's, and is established in Pennsylvania, New York, and New Jersey *(697)*.

Family Mutillidae
Velvet Ants

Members of the family Mutillidae are commonly known as velvet ants. The females are wingless, have heavy coatings of fine hairs, and are usually observed running back and forth over the ground. In certain regions they are also known as "cow-killers." Adults are usually brightly colored with red, orange, or yellow markings, and some of the females are 25 mm or more in length. The majority of species are parasitic on ground-nesting bees and wasps *(844)*. A common species in the South, where members of the family are most prevalent, is *Dasymutilla occidentalis occidentalis* (L.). Velvet ants are capable of inflicting painful stings.

Family Scoliidae
Scoliids

The family Scoliidae is represented by about 12 species in the Eastern United

States and, as far as known, all are external parasites of scarabaeid larvae in the soil. The adults are large, hairy, and usually black except for spots or bands of yellow or red, and the wings are often dark brown with purple or green iridescence. *Campsomeriellia annulata* (F.), a native of China and Japan, was introduced against the Japanese beetle in the 1920's but did not become established.

Family Sapygidae
Sapygids

As far as known, all members of this family are parasitic on the larvae of leafcutting bees and possibly of the large carpenter bees. Less than a dozen species are recorded from the Eastern United States. Adults are moderate in size, short-legged, and usually spotted or banded with yellow.

Family Formicidae
Ants

Ants are among the most abundant and widespread of all insects and are found in practically all terrestrial habitats. The majority of species nest in soil. Others nest in wood, timbers, in or under the bark of decaying trees, or in hollow stems of plants. Some of the more primitive species feed on insects or other small animals which they are able to kill. Many others feed on sweet fluids such as sap exuding from wounds, on nectar, or on honeydew produced by other insects. Certain leafcutting species cultivate fungi on which they feed.

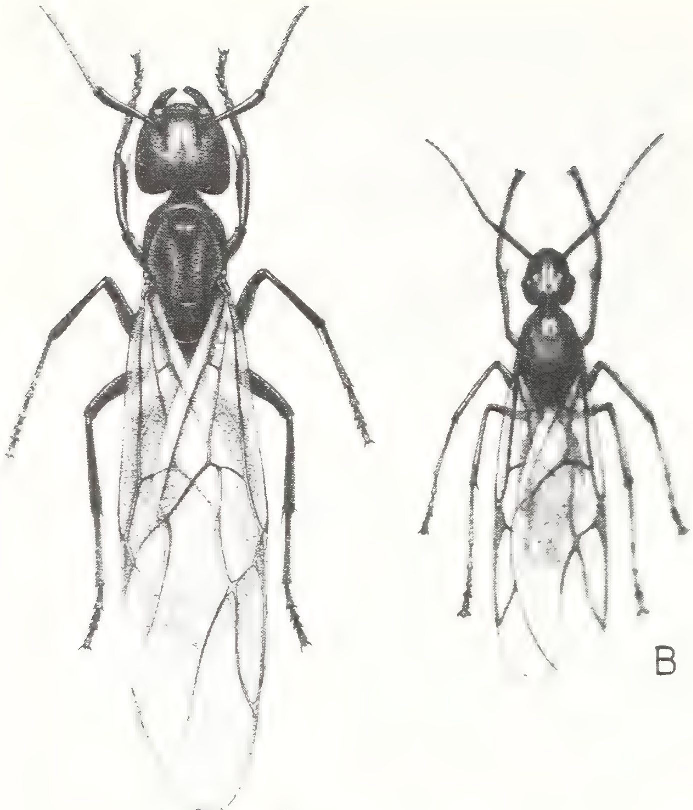
Ants differ from their near relatives in having the abdomen divided into two distinct regions, the pedicel and the gaster. Also, the antennae are elbowed, with the first segment greatly elongated in females and workers. They also differ from termites, with which they are often confused, by having a strong constriction or "waist" between the thorax and abdomen, and by having two pairs of wings of unequal size.

Ants are social insects and live in nests or colonies, each containing from a few to several thousand individuals. A colony consists of three castes—reproductive females, males, and workers. Females generally are winged, the wings being discarded after they mate. Males are usually smaller than females and generally retain their wings until death. Workers are wingless and usually smaller than reproductive females or males.

With the exception of the carpenter ants and certain leafcutting species, ants are of minor importance as enemies of trees or wood products. Many species, however, are nuisance pests in forested areas, especially in picnicking or other recreational areas. Several publications on the biology and control of carpenter ants are available *(458, 1052, 1083, 1110).*

The **black carpenter ant**, *Camponotus pennsylvanicus* (De Geer), nests in live and dead standing trees, rotting logs and stumps, telephone and telegraph poles, and wood of houses and other buildings. It is widely distributed in the Eastern United States and Canada, occurring from North Dakota to Quebec and Ontario and south to Texas and Florida. These large ants (fig. 206) include workers ranging in length from 6 to 13 mm. The body is typically black, but in some individuals the pleuron, petiole, and legs are reddish. The gaster is covered with dense, long, appressed, pale yellowish and ashy pubescence. Body hairs are suberect or erect, yellowish, and moderately abundant.

The black carpenter ant does not eat wood. It simply removes it in order to produce galleries which serve as its nest. Its natural food consists largely of dead and live insects, honeydew, sap, juices of well-ripened fruits, and refuse. It also feeds on various household foods such as different kinds of sweets, raw and cooked meats, and fruits.



Courtesy Conn. Agric. Exp. Stn.

Figure 206.—Black carpenter ant, *Camponotus pennsylvanicus:* A, adult winged female; B, adult winged male.

Live trees are infested occasionally but usually only when the ants are able to enter through cracks, scars, knotholes, and decayed or other faulty places. Once inside, they remove faulty wood and often extend their galleries into adjacent sound wood. A wide variety of trees such as poplar, cherry, eastern white and pitch pines, balsam fir, elm, willow, and red, white, scarlet, black, and post oaks have been infested. Infestations frequently are located near the base but may occur very high in a tree. Infested trees are often subject to serious injury. They are frequently weakened to the point that they are subject to windbreakage. The wood also may be rendered worthless for lumber or pulpwood (fig. 207).

Often houses are invaded by carpenter ants coming from nearby nests. This happens frequently where houses are located in the vicinity of trees, logs, or stumps. Entry is frequently gained through openings around the foundation of the house or from tree branches in contact with the house. The woodwork may be attacked in any number of places, but the most commonly damaged parts are supporting timbers, porch pillars, sills, girders, joists, studs, window casings, and external trim. The galleries are similar to those constructed by termites except that they run across the grain, are sandpaper smooth, and free of frass. Evidences of infestation are the presence of large black ants running about the house, swarms of large black, winged ants about the house in spring, piles of sawdustlike borings, slitlike holes in woodwork such as window and door casings, and faint rustling sounds in walls, floors, woodwork, and flush-panel doors. Where infestations are of long standing, damage to structural timbers may be severe and require extensive repairs. Telephone and telegraph poles also are subject to serious damage (fig. 208) *(451)*.

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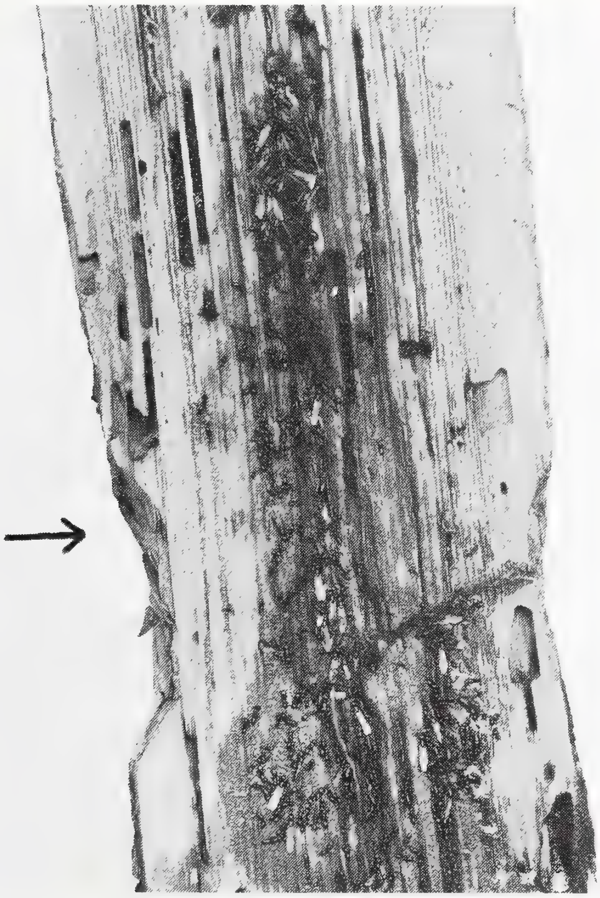
Figure 207.—Cross section of an oak log showing galleries made by carpenter ants.



Courtesy Conn. Agric. Exp. Stn.

Figure 208.—Colony of carpenter ants in a 0.6-m section of a telephone pole in winter. Arrow indicates ground level.

Overwintering males and females in colonies over 3 years old engage in nuptial flights from May to late July. Fertilized females then establish nests in cavities, usually under the bark of a tree, log, or stump, and seal themselves inside. Here they rear their first broods of workers to maturity on salivary secretions. These workers, being inadequately fed, are smaller than normal. Subsequent broods are fed by the workers, and individuals are larger. Long-established colonies contain workers of various sizes, some of which are extraordinarily large. Such colonies may consist of a reproductive female, scores of winged males and virgin females, and several thousand workers.

Tightly constructed houses with concrete foundations, good clearance, and full basements are fairly safe from invasion by black carpenter ants. Removing all wood from near or under a house site before construction, making certain that infested wood is not brought into the house, and cutting back branches in contact with the house are also helpful in preventing infestations in buildings.

The **red carpenter ant**, *C. ferrugineus* (F.), occurs over much of the same portion of the United States as the black carpenter ant, but is apparently less common. It appears to prefer wooded areas where it nests in or beneath well-rotted logs and stumps. Under these conditions, it often extends its galleries for considerable distances in the soil. Nests are also found in dead, standing trees but rarely in houses. The workers are about the same size as those of the black carpenter ant. Most of the thorax, petiole, base of the gaster, and much of the legs are yellowish ferruginous. The remainder is black. Hairs and pubescence are more golden yellow than those of the black carpenter ant, especially on the gaster. This species has caused considerable damage to standing northern white-cedar in Minnesota *(494)*.

The **Florida carpenter ant**, *C. abdominalis floridanus* (Buckley), occurs from North Carolina to Florida and Alabama. It is one of the most important house-infesting species in Florida. Workers are about 5.5 to 10 mm long. The head is reddish, the thorax and petiole yellowish or yellowish red, the scape and gaster blackish or black, and the body is covered with many long yellowish hairs. This species builds its nest in various places such as in the ground beneath objects, in dead branches in trees, in and beneath rotting logs and stumps, and sometimes in the woodwork of porches, roofs, kitchen sinks, and paneling. Outdoors, the ants feed largely on living and dead small insects, and on honeydew which they secure by tending aphids, mealybugs, and scales. Indoors, they feed on such items as molasses, honey, and raw and cooked meats.

Camponotus nearcticus Emery usually nests in small colonies in dead twigs and branches of trees, in or beneath the bark of dead and living trees, in insect galls and pine cones, in the hollow stems of plants, and in wooden posts. Nests have also been found in the woodwork of houses, especially in roofing. It occurs from New York to Ontario, North Dakota and Colorado, and south to Mississippi and Florida. Workers are about 4.5 to 7.5 mm long, and their bodies are usually black and rather shiny.

Camponotus sayi Emery occurs from North Carolina to Florida and west to Colorado and California, but is apparently most common in the Gulf Coast States. It nests in small colonies in tunnels made by borers in the twigs and branches of various hardwoods, in insect galls, in cavities in the stalks of plants, under the bark of trees, and in logs, stumps, wooden posts, and houses. Galleries in branches may be anywhere from 2 cm to over 1.5 m long. Workers are 4 to 9 mm long. The head, thorax, and petiole are usually yellowish red or reddish, and the gaster is blackish or black. *C. caryae discolor* (Buckley), a species similar in appearance and habits to

C. sayi, has been recorded from Ohio to Kansas and Iowa and south to Texas and Florida. It is most common in the lower Mississippi Valley. *C. castaneus* (Latreille) occurs throughout the South but is most common in the Southeast. It nests in rotten logs and stumps or in the soil. Workers are yellowish to yellowish red and from 7 to 10 mm long. *C. tortuganus* Emery occurs in the southern half of Florida and apparently nests in small colonies in rotting wood or in the soil beneath stones. It also occurs in houses where it may be a pest. *C. mississippiensis* M. R. Smith has been found nesting in the new growth of white ash branches in Mississippi. Galleries are apparently limited to 1 year's growth. *C. pylartes fraxinicola* M. R. Smith nests in the dead branches of various hardwoods. It has been recorded from Mississippi.

The **Texas leafcutting ant**, *Atta texana* (Buckley), is a serious pest of pine seedlings in eastern Texas and west-central Louisiana. It also defoliates and damages a wide variety of other plants, including orchard trees. Injury to pines is especially severe during the winter when there is a dearth of other green foliage.

Texas leafcutting ants are rusty red. The head is strongly bilobed, the antennae are 11-segmented and without a well-defined club, the thorax bears three pairs of prominent spines on top with the anterior ones the largest, and the legs are extraordinarily long. The queen is about 18 mm long; workers, from 1.5 to 12 mm long.

Nests of the Texas leafcutting ant are constructed in the ground, usually in well-drained sand or loamy soils and commonly on slopes facing the south or west *(95)*. The interior of the nest may reach a depth of 6 m. It may contain a thousand or more entrance holes. Nest areas are usually marked by many crescent-shaped mounds up to 12 to 35 cm high and 30 cm in diameter. Each mound surrounds an entrance hole (fig. 209). The nest consists of many cavities connected by narrow tunnels. There are vertical tunnels that extend to mound openings and lateral tunnels that lead outward, sometimes for 90 m or more. Above ground, sharply defined foraging trails sometimes extend hundreds of meters to the plants under attack. Ants move in procession along these trails, each carrying a fragment of leaf or other material to the nest. These fragments, which may be several times the size of the ants carrying them, are borne upright over the head like a parasol.

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Figure 209.—Mounds of the Texas leafcutting ant, *Atta texana*.

The ants do not eat the foliage that they remove from plants. Instead, they cut it up into small fragments, shape it into small pellets, and carry it into their underground chambers. Here it is placed upon so-called gardens, where it serves as a medium for the growth of a fungus. It is this fungus that serves as the food of the colony. Through the summer, most of the foliage is brought into the nest during the night; in the fall, winter, and spring, most of it is brought in during the day, unless it is too cold or wet *(369)*.

Winged males and females appear during May and June and fly from the colony and mate. Mated females lose their wings and dig into the soil where they establish nests. Here they become the queens of new colonies.

The **Allegheny mound ant**, *Formica exsectoides* Forel, is a serious pest of young eastern white, red, and Scotch pines, eastern redcedar, and spruce in the Eastern and Northeastern States. It nests in the ground and constructs mounds that may be up to 1.2 m in height and 1.8 m across. In forested areas, these mounds are most often found in openings or along the edges of stands. All vegetation, except large trees, may be destroyed in an area 12 to 15 m in diameter around a mound. Trees from 2 to 15 years old are especially susceptible to attack. Damage may be severe in forest plantations. The adult ant is about 3 to 6 mm long. The head is reddish brown and about as wide as it is long, the thorax is reddish brown and feathered, the anal region is reddish and surrounded by a fringe of hairs, and the legs are sometimes brownish or dark red.

The Allegheny mound ant does not feed on trees or other vegetation. Its food consists of living and dead insects and honeydew excreted by various species of sucking insects. It appears that the only reason it attacks vegetation is to kill it to keep it from shadowing the mounds. Trees are killed by the injection of formic acid into their tissues. Apparently this results in the coagulation of cell contents and the prevention of the downward movement of foods in the inner bark *(976)*.

The life history of the Allegheny mound ant is not too well understood, but this ant is known to forage for food from April to September and to spend the winter in its nest. There are several generations per year and both queens and workers are known to live for several years.

Crematogaster cerasi (Fitch) occurs from southern Canada to Georgia. Its nests are found in the ground, in rotting stumps, logs, or branches, and in empty nuts on the ground. Nests also may be found in various parts of houses such as the roof, siding, ceiling, and porch, but most often in and around door and window frames. *C. clara* Mayr occurs from Indiana to New Jersey and south to Texas and Florida, but is most common in the lower Mississippi Valley. Its nests are found in cane stems, branches, trees, rotten stumps, and sometimes in the woodwork of houses. *C. lineolata* (Say) occurs in southern Canada and throughout the Eastern United States. It constructs fairly large nests, usually in the soil, but also in logs, stumps, dead trees, or in the woodwork of houses. When alarmed, the workers bite fiercely and give off a repulsive odor. *C. laeviuscula* Mayr and *C. ashmeadi* Mayr have been recorded nesting in various dead hardwoods in Mississippi.

The **Argentine ant**, *Iridomyrmex humilis* (Mayr), an introduced species first recorded in this country at New Orleans in 1891, now occurs in many localities in the Southern States and California. Local infestations have also been found in St. Louis, Baltimore, and Chicago *(1110)*. Indoors, it feeds on almost every kind of food, especially sweets, meats, pastries, fruit, eggs, dairy products, animal fats, and vegetable oils; outdoors, it feeds partly on honeydew produced by aphids, mealybugs, and scale insects. By fostering and protecting the latter insects from

many of their enemies, they encourage the development of heavy infestations that are capable of causing serious damage to affected plants. They also remove seeds from seed beds and feed on the sap or fruit juices from various trees and plants.

Argentine ants are more or less uniformly light brown or brown, the antennae are 12-segmented and without a club, and the petiole scale is well developed and inclined. Workers are from 2.2 to 2.6 mm long; when freshly crushed, they emit a stale, greasy, musty odor. Nests occur in many kinds of places, such as in the soil, in rotten wood, in cavities in trees, in refuse piles, and in bird nests and beehives. The number of ants present in well-established infested areas is beyond comprehension. Fortunately, they are usually of minor importance as pests in forested areas.

Iridomyrmex pruinosus (Roger) occurs throughout the Eastern and Southern States north to New York and Wisconsin. It nests in the ground and under the bark of logs and stumps, and is sometimes a nuisance in houses. The odor of freshly crushed workers resembles that of rotten coconut.

The genus *Solenopsis* is represented by eight species in the United States, seven of which occur in the Southeastern States. They are commonly called fire ants. Nests are usually constructed in the soil, but also sometimes in rotten wood and in houses. The workers are aggressive and practically omnivorous.

The primary diet of fire ants is insects, spiders, myriapods, earthworms, and other small invertebrates. They also may feed on plants, particularly seedlings or germinating seeds. Other economically important problems created by the imported fire ants are stinging of livestock, damage to farm machinery that strike mounds, loss of hay and grazing area, refusal of workers to enter heavily infested fields to cultivate or harvest crops, and hazards to human health from stings that may cause systemic reactions or complications from secondary infections *(749)*.

Both the **red imported fire ant**, *Solenopsis invicta* Buren, and the **black imported fire ant**, *S. richteri* Forel, were introduced from South America into the United States at Mobile, Ala.—the former, about 1940 and the latter, about 1918. *S. richteri* is more or less stable in a relatively small area in northeastern Mississippi and northwestern Alabama. *S. invicta* is more widespread and is now found in nine States from the Carolinas to Texas. It is still spreading in all directions although the northward spread is slow *(749)*. The two species are often very difficult to distinguish on the basis of color alone. Detailed examination of morphological characters such as the shapes of the head, thorax, and postpetiole is needed to separate these species *(172)*.

Imported fire ant mounds are found in almost all kinds of soil, but most commonly in open areas. Few if any are ever found in heavily timbered areas, especially in hardwood stands. An average mound is about 30 cm high and 60 cm across; some are up to 90 cm tall. The larger ones are usually dome-shaped or conical, and may contain more than 100,000 ants. In heavily infested areas there may be more than 30 nests per hectare. Nests are also found in rotting logs, around tree trunks, and occasionally under buildings. The biologies of these species have been discussed *(501)*. Comprehensive treatments of ants may be found in the literature *(265, 1109, 1282)*.

Superfamily Vespoidea

This superfamily comprises two families, the Vespidae and the Pompilidae. Many species are social in habit and live together in colonies; others are solitary and live alone. The adults generally feed on nectar, sap, honeydew, or similar materials, whereas the larvae feed on other insects or spiders provided by the adult female. The larvae of some species feed on pollen and nectar. A few species are of

some importance as pests of forest or shade trees; quite a number of other species may create problems when they occur in abundance in picnicking areas, campgrounds, or other recreational areas.

Family Vespidae
Hornets, Yellowjackets, and Potter Wasps

The family Vespidae contains the well-known stinging wasps, hornets, and yellowjackets. More than 360 species have been recorded in America north of Mexico, about one-third of which occur in the Eastern United States. Considered as a whole, these insects are not very important as forest pests since very few of them are capable of inflicting serious injury to trees. Adults of the family differ considerably in size and appearance, but all are distinguished by the very long discoidal cell in the forewings, and by their common habit of folding their wings longitudinally while at rest. Some of the more common species live in nests or colonies containing a few to several hundreds or thousands of individuals. A synoptic catalog of species occurring in America north of Mexico is available *(697)*.

Social species construct nests out of papery material consisting of wood or foliage chewed up and elaborated by the insect. Hornet nests contain several to many tiers of hexagonal cells enclosed in a papery envelope and are usually attached to the limbs of bushes or trees or to the eaves of buildings. They are roughly spherical and often quite large, measuring 75 mm or more in diameter. Yellowjackets also construct nests of papery material, but these are usually placed out of sight in the ground, in stumps, or under objects. An exit hole leads to the outside. Wasp nests usually consist of a single horizontal comb or layer of cells attached to a support by a slender stalk. They may be found in many places, such as under the eaves of roofs, under porches, in open sheds, and on bushes, shrubs, and trees. The adults of all members of the family feed commonly on nectar, ripe fruits, sap, and honeydew. The larvae feed on other insects provided by the adults.

The **European hornet**, *Vespa crabro germana* Christ, an introduced species, has been recorded from Quebec and Massachusetts to Alabama and North Dakota. According to reports, hollow trees, hollow posts, sheds, barns, porches, and even attics are preferred as nesting sites. These nests occasionally become very large, reaching a length of 90 cm and a diameter of 50 cm. There are reports of damage to trees and shrubs by the adults *(1077)*. They may girdle small twigs and gnaw holes in the bark of larger branches, possibly in search of nest-building materials and sap. Injuries have been reported to lilac, birch, ash, and buckeye. The adults possess a long stinger and a large poison sac. This species is capable of inflicting painful stings, but does not appear to be as likely to attack when disturbed as is the baldfaced hornet.

The **baldfaced hornet**, *Vespula maculata* (L.), a well-known member of the family, is widely distributed in the United States and Canada. Adults are 12 to 19 mm long, largely black with white markings on the face and thorax, and with the posterior third of the abdomen white. It commonly attaches its nests to the limbs of trees or bushes, also occasionally to the walls and windows of houses. These nests may reach a diameter of 38 cm and contain up to several hundred hornets each. Baldfaced hornets attack at once when their nests are disturbed, and are capable of inflicting extremely painful stings.

Vespula arenaria (F.), the **yellowjacket wasp**, and *V. maculifrons* (Buysson) are two of the more common species of yellowjackets in the Eastern United States. The former also occurs throughout the remainder of the United States, in Canada, and Alaska north to the Arctic Circle. *V. arenaria* belongs to the group of aerial nesters

(subgenus *Dolichovespula)* and is not a scavenger. Nests (fig. 210) are typically built in trees, low brush, or just above ground in vegetation, not beneath the ground. Thus they would not be picnic pests unless their nest was built on or very close to the picnic table.

Courtesy Conn. Agric. Exp. Stn.

Figure 210.—Nest of the yellowjacket wasp, *Vespula arenaria*.

The **eastern yellowjacket**, *V. maculifrons* (subgenus *Vespula)*, along with *V. squamosa* (Drury), may be the two most troublesome species in the Eastern United States *(778)*. *V. maculifrons* also occurs in southeastern Canada. Adults of *V. maculifrons* are black and yellow with black predominating. The legs are yellow with the femora partly black. Nests are usually built in the ground, frequently in yards, and may attain very high densities in recreational areas. This species also inflicts severe stings and it often attacks in force when its nest is endangered. It is a common species around picnic tables where it is often a nuisance. The adventive species, *V. germanica* (L.), nests above ground and commonly builds its nest in attics and walls of homes.

Vespula squamosa is the most common yellowjacket from central Georgia into Florida and probably along the Gulf Coast. This species was recently found to be a social parasite of *V. maculifrons (779)* and the extent of its scavenging habits is still in question. A discussion of various methods of control of yellowjackets and their effectiveness has been published *(778)*.

The genus *Polistes* contains the familiar wasps whose nests are so frequently encountered hanging under the eaves of buildings and in a variety of other places. They differ in appearance from the hornets and yellowjackets in having long and spindle-shaped abdomens. The nest consists of a single comb suspended by a peduncle, and it is not enclosed in an envelope. It is usually rather small, although

some may be 75 mm or more in diameter. The adults of a number of species collect lepidopterous larvae as food for their young, and where abundant, are apparently capable of exercising a considerable degree of control of their hosts. Like hornets and yellowjackets, these insects are vicious stingers, and their nests should be approached with caution.

Family Pompilidae
Spider Wasps

Members of this family are predacious or parasitic on various species of spiders. The adults are often seen visiting flowers and are noted for their extreme activity and ability to run. Their nests are usually found in the ground, but those consisting of mud cells are constructed under logs or stones and in other protected places such as holes in wood.

Superfamily Sphecoidea

All members of this superfamily are predacious on other insects. The majority of species nest in burrows in the soil; the remainder build nests of clay, mud, or sand, or in the stems of plants or various kinds of cavities in which they store paralyzed prey for their progeny. Host preferences are varied and include spiders and most of the more common orders of insects. Adults generally can be recognized by the structure of the pronotum that does not extend back to the tegulae, by their unjointed trochanters, by the absence of dilation in the hind tarsus, and by the simple pubescence of the head and thorax.

Family Ampulicidae
Ampulicids

This family is represented in North America by only two genera and three species. As far as known, they nest in twigs, under bark, and under litter on the ground. Their prey consists of immature cockroaches.

Family Sphecidae
Cicada Killers, Mud Daubers, and Sand Wasps

This family is represented by 111 genera and more than 1,100 species in the United States and Canada. The majority are solitary nest-building wasps that provision their nests with other insects or spiders. Many species nest in the ground; some construct nests of mud and attach them to the ceilings or walls of buildings, or to the lower surfaces of other objects; others construct their nests in the stems of plants. Adults are distinguished by the collarlike pronotum that has a straight hind margin, the cylindrical rather than flattened hind basitarsus, and absence of branched body hair. In a few species, such as the familiar daubers, the abdomen has a long, cylindrical petiole.

The **cicada killer**, *Sphecius speciosus* (Drury), which provisions its nest with adult cicadas, is one of the more conspicuous members of the family. The adult female is a large, black or yellow wasp up to 37 mm long. There are prominent black and yellow bands or spots on the abdomen. Adults are usually present from midsummer to early fall and they burrow into the ground for nesting purposes. The female paralyzes a cicada by stinging it and then flies it to her nest, stores it in a cell, and deposits an egg between its legs. When the larva hatches it feeds on the cicada. There is one generation per year.

Cerceris fumipennis Say provisions its nest with a wide variety of wood-boring buprestids. Species of the genus *Psen* prey on various membracids, cercopids, and leafhoppers; *Crossocerus annulipes* (Lepeletier & Brulle) preys on various species of tree-infesting cicadellids *(281)*; *Stictia carolina* (F.) is frequently seen hovering over livestock in search of horse flies.

Superfamily Apoidea
Bees

It has been estimated that more than 3,500 species of bees in 7 families occur in North America. Some Apidae such as the honey bee and bumble bee, are so common as to require no description. Fortunately, none of these insects is particularly injurious to forest or shade trees. On the contrary, as a group they are highly beneficial because of the prominent role so many of them play in the pollination of flowers. While the majority of species provision their nests with pollen and honey, a few lay their eggs in the cells of other bees where their young live as inquilines or parasites and feed on food stored by their hosts. Members of the superfamily are distinguished by the following characteristics: the pronotum does not extend back to the tegulae, the trochanter is single-jointed, the hind basitarsi are dilated or thickened, and the head and thorax are covered with branched hairs.

Family Megachilidae
Leafcutting and Mason Bees

Leafcutting and mason bees are small to medium size and black, blue, brown, gray, metallic, or purplish. Some are marked with yellow. They build their nests in rotten wood, in holes in solid wood, and in the hollow stems of plants, and they line the walls of their cavities with mud, resin, or circular or oval-shaped pieces of leaves cut from various species of plants. A few species have been recorded damaging shade trees and ornamentals in various parts of the country; otherwise, the group is noninjurious.

Family Anthophoridae
Digger, Carpenter, and Cuckoo Bees

The family Anthophoridae is represented by more than a thousand species in the United States and Canada. It has been divided into three subfamilies—Anthophorinae, Xylocopinae, and Nomadinae.

The subfamily Anthophorinae contains the so-called mining or digger bees and the cuckoo bees. A number of species collect pollen and nest in the ground. Certain others, such as the cuckoo bees or Nomadinae, are parasitic in the nests of other bees. The adults are usually wasplike in appearance. Members of the subfamily Xylocopinae construct their nests in wood or plant stems and are commonly known as carpenter bees. The genus *Xylocopa* contains the large carpenter bees. The adults look like bumble bees but differ in having the dorsum of the abdomen largely bare. They nest in solid wood.

Considered as a whole, members of the family are far more beneficial than harmful. Many species are highly efficient plant pollinators, and the only destructive members of the family are the carpenter bees, several species of which attack and damage wood in use.

The **carpenter bee**, *X. virginica* (L.), is an important pest because of its habit of tunneling into the solid wood of beams, rafters, telephone poles, or structural timbers. This activity may lead to structural damage, especially when the same piece of timber is attacked for several years. Dead but sound wood of baldcypress, thuja, eastern white and hard pines, and redwood seems to be preferred. The adult, which is about 25 mm long, bores a hole about 9 mm in diameter straight into the wood for a short distance, then makes a right-angle turn and follows the grain of the wood for a distance of 15 to 20 cm. Sometimes two bees use a common entrance hole. When this happens the tunnel is extended in opposite directions from the entrance hole. Eggs are deposited singly in separate chambers in the tunnel, each of which is largely provisioned with pollen. Each larva lives and feeds in its chamber until mature. Adults feed on pollen during daylight hours. Females spend the night

in their burrows, and males, under boards or in other protected places. Winter is spent as young adults in their tunnels. There is one generation per year.

Living bees in tunnels can be killed by running a stiff wire all the way to the end of the tunnel.

One other species of carpenter bee, *X. micans* Lepeletier, also occurs in the Eastern United States from North Carolina to Florida and westward along the Gulf Coast.

Order Diptera—*Flies*

The Diptera constitutes one of the largest orders of insects. The majority of species differ from other insects to which the term "fly" is applied, such as the sawflies, stoneflies, and the dragonflies, by the fact that they posses only one pair of wings, the forewings. Their hindwings are reduced to small knobbed structures called halteres. The majority of species are soft-bodied and small to minute in size. The larvae, commonly known as maggots, are legless, and vary in form from slender and elongate to stout and cylindrical. The pupae may be free, loosely enclosed, or held immobile in the last larval skin. In the latter case it is known as a puparium.

Many species of Diptera are destructive pests and are of great economic importance. Bloodsucking forms such as the mosquitoes, black flies, punkies, and horse flies are serious pests of animals, including humans. Some of these as well as some of the scavenger species, such as the house fly, are important vectors of the causative organisms of such serious diseases as malaria, yellow fever, filariasis, dengue, sleeping sickness, and dysentery. A number of others are important pests of agricultural crops, a few are pests of trees and ornamental plants, and many are important parasites or predators of injurious species of insects.

Several native and introduced species are highly effective parasites of some of our most destructive tree-defoliating insects, especially of the order Lepidoptera. A few aquatic species, some of which are nuisance pests in the adult stage, are economically important as fish food in the larval stage.

Several comprehensive treatments of the order Diptera have been published *(165, 273, 1175, 1192, 1313)*.

Families Oestridae and Cuterebridae
Bot and Warble Flies

Bot and warble flies are endoparasites of animals, and several are serious economic pests. They are best known as enemies of domestic animals, but many species also attack various wild animals. The adults are medium- to large-size flies resembling bees. Members of the genus *Cephenemyia* infest the nasopharyngeal region of deer, moose, elk, caribou, and reindeer. The **northern cattle grub**, *Hypoderma bovis* (L.), and the **common cattle grub**, *H. lineatum* (Villers), are subcutaneous parasites of cattle, causing serious damage to the tissue and hides. The genus *Cuterebra* contains a large number of species that are subcutaneous parasites of various rodents and lagomorphs.

Family Culicidae
Mosquitoes

Mosquitoes are important pests of people and other animals. Not only are their bites extremely annoying, but they transmit many of the most serious diseases of humans and other animals, such as malaria, dengue, yellow fever, and encephalitis *(431)*. As nuisances, they often seriously interfere with public enjoyment of parks, vacation sites, and other recreational areas. Woods workers, fishers, hunters,

vacationers, and hikers are also pestered by them. The health of domestic animals and wildlife suffers with serious losses of weight and disease.

Twelve genera and 148 species of true mosquitoes occur in the United States and Canada *(1173)*. The larvae and pupae live in standing or slowly moving bodies of water that range in size from small accumulations held by plants to vast salt marshes. Many of these are included in a review of mosquitoes in the Southeast *(666)*.

Family Ceratopogonidae
Biting Midges

This family contains a number of species of very tiny flies, usually 1 to 4 mm in length, that feed on the blood of humans and other animals. They are often abundant in the vicinity of fresh water inlets along the seashore or near fresh water streams, ponds, and pools. Woods workers, hikers, hunters, fishers, picnickers, and others frequenting these areas often find their presence almost intolerable because of their very burning and painful bites. Populations are heaviest during late summer. At this time, these flies bite chiefly in the evening and very early in the morning. Some 27 genera and 348 species occur in America north of Mexico *(1341)*.

Family Chironomidae
Midges

Midges are small, slender flies, rarely over 10 mm in length *(1177)*. They resemble mosquitoes, but do not have fringes of scalelike hairs on the wings. They differ also by the discontinuation of the costal vein at the end of the third vein. Midges are frequently seen in great swarms, dancing in the air, usually in the evening. The larvae of most species are found in the water of streams, usually attached to the surface of stones, sticks, and other objects. Many are red and are commonly known as bloodworms. Midge larvae are fed upon by many freshwater fishes and other aquatic animals.

Family Simuliidae
Black Flies

Black flies occur in nearly all parts of the United States and Canada *(1174)*. In different parts of their range they have various common names such as buffalo gnats and turkey gnats, as well as black flies. The females feed on the blood of humans and other animals and their bites cause swelling, itching, and sometimes bleeding. Their habit of hovering about the face and getting into the eyes, ears, and nostrils makes them a nuisance. When they appear in large numbers, birds and animals may be literally smothered by flies drawn into their air passages. In the woods and mountains of the Northern United States and Canada, they are often so abundant in the spring that they are almost unbearable. Black flies have also been incriminated in the transmission of several diseases of wild and domestic birds.

Black flies usually lay their eggs on grass and other materials just below the surface of water in swiftly flowing streams. The larval stage is spent in the water, usually attached to sticks, stones, or living vegetation. Adults are not strong fliers and usually are encountered in large numbers not too far from streams. Sometimes, however, the wind blows them a considerable distance.

Family Bibionidae
March Flies

March flies are slender-bodied, stout-legged, rather hairy, and have short, many-jointed antennae. They are usually dark, but may be marked with red or yellow. Full-grown larvae are distinguished by a fully developed false segment, armed with spines behind the head. The common name, March flies, has been applied to the

group because of the frequent appearance of the species, *Bibio albipennis* Say, in large numbers in March. Because of its huge numbers, *Plecia nearctica* Hardy, the **lovebug**, is a nuisance to drivers in the Gulf States. The larvae usually feed on decaying vegetable matter, but a few feed on the roots of grass and other plants.

Family Sciaridae
Darkwinged Fungus Gnats

Darkwinged fungus gnats are moderately small, slender, delicate, mosquitolike insects. The antennae have 12 to 17 segments, the wings are large, the coxae are prominent and elongated, and the tibiae are armed with spurs. The adults are often common in dark, humid habitats in wooded areas. Many species breed on mushrooms or on fungi growing on trees and logs. A number of others are predacious and are found under bark or in the galleries of wood-boring insects.

Family Cecidomyiidae
Gall Midges

There are more than 1,000 described species of Nearctic cecidomyiids, of which several hundred are known to attack various trees and shrubs *(430)*. The oaks are especially favored as hosts but several other species of trees are also infested, such as willow, elm, maple, walnut, hickory, and the pines. The larvae of about two-thirds of the species cause the formation of galls or pronounced swellings by their feeding *(400)*. Others feed in such places as patches of pitch exuding from injured limbs, on fungi, in the excrement of insects, birds, and mammals, and in galls produced by other insects. A few are predators on small insects such as aphids, mites, psyllids, and scales.

Gall midges are small, mosquitolike flies with relatively long antennae and legs. Young larvae are slender, somewhat flattened, and taper toward each end. Full-grown larvae are distinguished by the presence of a sclerotized structure, commonly known as a spatula, on the underside of the front end.

The **balsam gall midge**, *Paradiplosis tumifex* Gagné, produces swollen, oval galls about 3 mm in diameter near the bases of needles of balsam fir *(951)*. It most likely also occurs on Fraser fir and wherever these hosts are found in North America. Damage in Christmas tree plantations may be severe because galled needles drop from the twigs in October.

Dasineura balsamicola (Lintner) originally was believed to be the cause of the gall formed by *P. tumifex (482)*. However, the role played by *D. balsamicola* is that of inquiline, and this midge kills the gall-former *P. tumifex* where they occur together. Closer study of other species of *Dasineura* may reveal similar relationships. *D. gleditchiae* (Osten Sacken), the **honeylocust pod gall midge**, produces oblong, podlike galls on the new leaflets of honeylocust seedlings in nurseries in the Midwest, New England, Oregon, California, and Pennsylvania. *D. pseudacaciae* (Fitch) attacks the young leaves of black locust and causes them to fold, and *D. communis* Felt, the **gouty vein midge**, produces greenish or reddish pouch galls on the veins of the leaves of red and sugar maples.

The **boxwood leafminer**, *Monarthropalpus buxi* (Laboulbène), an introduced species, occurs from Rhode Island south to Delaware and Maryland. Its hosts are different varieties of boxwood, the tree boxwood and the glossy leafed boxwood, in particular. Adults are orange-yellow and about 2.5 mm long. The larvae feed within the tissues of the leaf, causing blisterlike blotches up to 2.5 mm long by fall. Heavily infested leaves turn gray or yellowish brown and often drop prematurely.

Contarinia juniperina Felt, the **juniper midge**, is a pest of redcedar and other junipers in the Midwest and California. Adults are very small, only about 1.5 mm long, and have bright-red abdomens. Eggs are laid on the needles of new growth

near the tips of twigs. Larvae bore into the twigs at the bases of the needles and kill the portion beyond the entrance hole *(533)*. Heavily infested trees turn brown in the fall and most of the infested twigs break off during the winter. The hymenopterous parasite, *Platygaster pini* Fouts, is reported to have exerted a high degree of control of an outbreak in Missouri during the late thirties.

Contarinia negundifolia Felt, the **boxelder gall midge**, produces fleshy galls on the leaves of boxelder. It has been recorded from Virginia, the Lake States, and the Prairie Provinces of Canada *(1326)*. Other fairly common species of *Contarinia* include: *C. virginianiae* (Felt), the **chokecherry midge**, which feeds on the fruit of common chokecherry, causing it to become swollen and deformed; *C. cerasiserotinae* (Osten Sacken), which produces bright-red or yellow irregular bud or terminal galls on black cherry; *C. canadensis* Felt, which produces galls on the leaves of ash; *C. catalpae* (Comstock), whose larvae feed on the young leaves and seed pods of catalpa; and *C. verrucicola* Osten Sacken, the **linden wart gall**, which produces wartlike galls on the leaves of basswood.

Asphondylia ilicicola Foote larvae feed in the berries of American holly, and the infested berries remain green all winter. It has been recorded from New Jersey, Maryland, Virginia, and West Virginia *(569)*. The related species, *A. azaleae* Felt, produces the so-called pinkster bud gall on rhododendron.

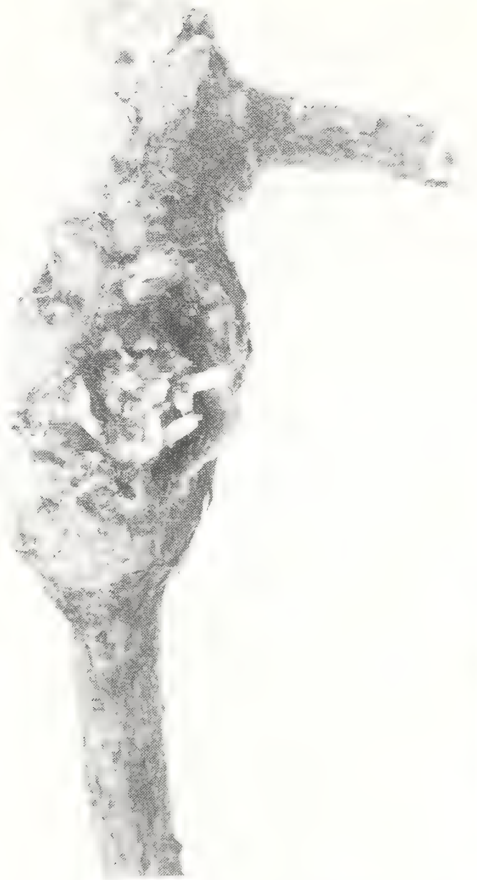
Thecodiplosis piniresinosae Kearby, the **red pine needle midge**, has been recorded causing the formation of gall-like structures in the bases of needle fascicles of red pine in Wisconsin *(657)*. Damaged needles turn brown in the fall and drop during the winter. The laterals and terminals of heavily infested trees may be killed. Heavy infestations appear to be confined to slow-growing trees.

Cecidomyia resinicola (Osten Sacken), the **gouty pitch midge**, causes swellings and malformations on the twigs of Virginia and pitch pines in eastern North America. It has a broad host range among hard pines and is widely distributed. Dead needles, dead or dying twigs, and distorted, twisted terminals are evidence of its attack *(355)*. The generally gregarious larvae of *C. resinicola* (fig. 211) are found in small patches of fluid resin exuding from wounds caused by their feeding. *C. piniinopis* Osten Sacken is another widespread resin midge with many host species among the hard pines *(460)*. Usually an individual larva occupies a drop of pitch at the base of a needle fascicle. When full grown the larva moves away from this site and spins a white cocoon in which it pupates. There may be several generations annually. *C. poculum* Osten Sacken produces clusters of pale or red saucerlike galls that are attached by slender stalks to the undersurfaces of oak leaves. *C. pellex* Osten Sacken produces reddish-brown bullet galls on ash. *C. ocellaris* Osten Sacken, the **ocellate gall midge**, causes the yellow galls margined with red that are often seen on the upper surface of red maple leaves.

Macrodiplosis foliora Russell & Hooker produces marginal fold galls on the leaves of black, red, and pin oaks.

Sequoiomyia cupressi (Schweinitz) feeds in the seeds and causes a leaf gall on baldcypress. *Taxodiomyia cupressiananassa* (Osten Sacken) also causes leaf galls on baldcypress.

Apagodiplosis papyriferae Gagné larvae feed in the buds of paper birch in the Lake States, causing the formation of galls (fig. 212). The galls surround the basal portions or all of one or two leaf petioles and either a bud or a part of the stem near the bases of the petioles *(1329)*. Damaged leaves fall prematurely and buds and branches are killed. Trees from 0.7 to 10 m tall are attacked. The younger ones are often badly deformed.



USDA, ARS, SEL

Figure 211.—Resin masses caused by feeding activity of larvae of *Cecidomyia resinicola*.

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Figure 212.—Damage to paper birch by the cecidomyid, *Apagodiplosis papyriferae*.

The **willow beaked-gall midge**, *Mayetiola rigidae* (Osten Sacken), produces apical, beaked galls on the lower branches of many species of willow (fig. 213). In Michigan, eggs are laid singly on or near the buds of the host. Newly hatched larvae penetrate the bud and a gall begins to develop by the end of the first instar and continues to enlarge until fall. Winter is spent as a larva inside the gall, and pupation occurs in the spring. The gall deforms the stem and occasionally a galled branch dies or breaks off *(1328)*.

F-519914

Figure 213.—Gall produced on willow by the willow beaked-gall midge, *Mayetiola rigidae*.

Many other species of gall midges have been recorded attacking various species of eastern trees. A few of the more common ones are: *Parallelodiplosis florida* (Felt)—produces elongate, pocketlike swellings on the veins and midribs of scrub and pin oak leaves; *Obolodiplosis robiniae* (Haldeman)—causes the margins of black locust leaves to fold; *Caryomyia holotricha* (Osten Sacken), *C. sanguinolenta* (Osten Sacken), and *C. tubicola* (Osten Sacken)—produce galls on hickory; *Polystepha pilulae* (Beutenmüller)—produces subglobose or globose, irregular, wrinkled, reddish galls on red oak leaves; *Janetiella coloradensis* Felt—causes swellings at the bases of Virginia pine needles; *Prodiplosis morrisi* Gagné—feeds on the young leaves of cottonwood in the South, causing them to turn black, unfold improperly, and frequently drop off; terminal growth is sometimes severely stunted. The **dogwood clubgall midge**, *Resseliella clavula* (Beutenmüller), produces clublike swellings on small twigs of dogwood, which sometimes kills up to 8 cm of the damaged twigs. *Semudobia* spp. feed on and destroy the seeds of birch.

Aphidoletes thompsoni Mohn, a European predator of the balsam woolly adelgid, has been released in aphid-infested stands of balsam and Fraser firs in the Northeast and the Southern Appalachians, but establishment is doubtful in the Southern Appalachians.

Family Xylophagidae
Ichneumonlike Flies

These flies, as their common names suggests, often resemble members of the hymenopterous family, Ichneumonidae. The adults are usually observed feeding on sap, the nectar of flowers, or other liquid matter in forested or wooded areas. The larvae appear to be either predators or scavengers in rich soil, in decaying vegetable matter, under the bark of trees, or in decaying logs. *Xylophagus lugens* Loew larvae may occur in large numbers under the bark of elm in association with the elm borer. The larvae of *X. abdominalis* Loew feed on beetle larvae under the bark of pine.

Family Stratiomyidae
Soldier Flies

Soldier flies are brightly colored, moderately large, nearly bare, and thinly pilose. Many species are wasplike in appearance but the majority are broad and greatly flattened, and their wings lie parallel upon each other while at rest. These flies occur chiefly in wooded or forested areas or in meadows near water. Many are attracted to flowers. The larvae are usually terrestrial but sometimes aquatic and act mostly as scavengers. *Zabrachia polita* Coquillett has been reared from decaying pine logs and from beetle-infested elm logs.

Family Tabanidae
Deer and Horse Flies

Many members of this family are important bloodsucking pests of livestock and wild animals. Some species also attack people and can be extremely annoying. Their bites are sharp and painful, and many are capable of removing considerable quantities of blood from their hosts, especially when they attack in force. They may also transmit such animal diseases as anthrax, anaplasmosis, surra, swamp fever, and tularemia.

Most of the large horse flies usually seen belong to the genus *Tabanus*. These flies breed mostly in marshes, swamps, bogs, and ponds. The largest and best known species is the **black horse fly**, *T. atratus* F. The adult is up to 25 mm long and its bite can result in the loss of a considerable quantity of blood. Other important species are: the **striped horse fly**, *T. lineola* (F.), *T. abactor* Phillip, *T. quinquevittatus* Wiedemann, *T. sulcifrons* Macquart, and *T. nigrovittatus* Macquart.

Deer flies belong to the genus *Chrysops* and are smaller than horse flies. They are active during the hottest weather and are often quite abundant during rainy spells. More than 60 species occur in the Eastern United States. *Diachlorus ferrugatus* (F.) is a common and notorious pest in swampy areas from New Jersey to Florida and Louisiana, especially in the Carolinas.

Family Rhagionidae
Snipe Flies

Snipe flies are commonly found in the woods, especially in moist areas. The majority are brownish or gray; others are black with spots or stripes of white, yellow, or green. Both the adults and larvae feed on other insects. Adults of the genus *Symphoromyia* fly persistently about the head and are very annoying because their bites are painful.

Family Asilidae
Robber Flies

Robber flies are mostly large to very large (fig. 214). Some have long, tapering abdomens; others are stout-bodied and resemble bumble bees. All are rather hairy. They are predacious on other insects and occasionally on their own kind. The larvae of *Tolmerus notatus* (Wiedemann), *Leptogaster flavipes* Loew, *Laphria index* McAtee, *L. flavicollis* Say, and *L. thoracica* F. have been collected from decaying wood infested with cerambycid and other coleopterous larvae. Larvae of certain other species feed on grasshopper eggs and white grubs.

Courtesy Conn. Agric. Exp. Stn.
Figure 214.—Adult of a robber fly, *Asilus sericeus*.

Family Bombyliidae
Bee Flies

These flies are moderately large, densely hairy, and look like bees. The adults are nectar and pollen feeders. The larvae of certain species are parasitic on the larvae of other insects, especially of the orders Lepidoptera, Hymenoptera, and Coleoptera. Others feed on the egg pods of grasshoppers.

Family Empididae
Dance Flies

Members of this family are commonly known as dance flies because of their habit of flying in swarms—up and down, up and down—in the woods, along streams, or

on the shores of ponds and lakes. The flies range in length from 1 to about 15 mm and probably are all predatory, mostly on small Diptera. The larvae live in damp earth, in decaying wood or other vegetation, under the bark of trees, or in the water. *Tachydromia* sp. has been reared from eastern white pine leaders infested with the white pine weevil.

Family Dolichopodidae
Longlegged Flies

Members of this family are very small, longlegged flies, rarely more than 10 mm long. Adults are predacious on other insects and are found on the foliage or trunks of trees, or on damp earth, usually in swamps or along lightly shaded streams. Most of the larvae appear to be aquatic, but those of a few species occur under the bark of trees where they feed on other insects. *Dolichopus vittatus* Loew has been reared from beetle-infested hickory, and *Medetera* sp. from beetle-infested larch and pine.

Family Pipunculidae
Bigheaded Flies

Pipunculids are small, dark flies with large heads composed mostly of large, approximated eyes. The larvae are small, elliptical, thick, depressed, naked, and narrowed at each end. They are parasitic on various families of Homoptera, especially the Cicadellidae.

Family Syrphidae
Flower Flies

This is one of the largest families in the order Diptera, and it is almost entirely beneficial *(840, 1342)*. The adults are strongly attracted to flowers and play important roles in the cross-pollination of plants and trees. The larvae of many species feed on and aid in control of many destructive insects such as aphids, scales, psyllids, spittlebugs, mealybugs, and lepidopterous larvae. A few species are plant feeders but they are seldom injurious.

Adults are usually brightly colored and are frequently striped, spotted, or banded with yellow. Some resemble wasps; others look like small bumble bees. The males have the peculiar habit of hovering almost completely motionless in the air and then darting swiftly to one side when disturbed. The maggots of insect-feeding species are sluglike. The body tapers toward the front end and the body contents are visible through the integument.

Family Conopidae
Thickheaded Flies

Conopid flies are thinly pilose or nearly bare, elongate, and of moderate size. The head is broader than the thorax, and the abdomen is elongated and constricted. The antennae are three-segmented, the third segment bearing a dorsal arista. Adults fly slowly and are usually seen around flowers. The larvae are solitary internal parasites, mainly of Hymenoptera. One species parasitizes grasshoppers and crickets.

Family Tephritidae
Fruit Flies

Fruit flies are fairly small and usually have spotted or banded wings. The larvae are usually pale yellowish and taper slightly toward the front. Eggs of most species are deposited in healthy, living tissue and larvae feed in various parts of plants. Certain species produce root and stem galls and a few are leafminers. Others develop in fleshy fruits or in the seeds or ovaries of flowers. Many species are highly destructive of fleshy fruits and vegetables throughout the world. A few of the species occurring in the woodlands or forests of the Eastern United States are discussed below.

The **apple maggot**, *Rhagoletis pomonella* (Walsh), an important pest of apple, also breeds in the fruit of hawthorn, common chokecherry, plum, and dogwood. The adult is dark colored and a little smaller than the house fly. Each wing is crossed by four dark bars that merge together. Three or four white bands run across the dorsum of the abdomen. The **cherry fruit fly**, *R. cingulata* (Loew), breeds in the fruit of cherry. Adults are black except for yellow margins on the thorax, two white crossbands on the abdomen, and a dark band on each wing. They are smaller than house flies. The **black cherry fruit fly**, *R. fausta* (Osten Sacken), breeds in cherry throughout the same area as does the cherry fruit fly. Adults resemble those of the cherry fruit fly except for the abdomen, which is entirely black. The **walnut husk fly**, *R. completa* Cresson, breeds in the husks of black walnut in the Central States. Feeding by the larvae produces a slimy condition that causes the husks to turn black, stick to and stain the shell. Nuts with damaged shells cannot be sold even though the contents are sound. The wings of the adult are transparent with dark crossbars. *Toxotrypana curvicauda* Gerstäker breeds in papaya in Florida and Texas.

Family Chamaemyiidae
Aphid Flies

The larvae of a number of species in several genera of these small, grayish flies are predators of aphids, scale insects, and mealybugs. One species, *Leucopis obscura* Haliday, a native of Europe, was introduced into Canada against the balsam woolly adelgid in the early thirties. It quickly became established and, following additional colonizations, spread over most of the infested areas in eastern Canada and into northern New England. Since 1954, colonies have been released in adelgid-infested stands in Vermont, New Hampshire, New York, North Carolina, and the Pacific Northwest. It is usually found on heavily infested trees only, where it feeds mostly on adults that have laid many eggs.

Cremifania nigrocellulata Czerny, another European species, also imported into eastern Canada and the Pacific Northwest against the balsam woolly adelgid, is now established. A fairly large number have developed on stem-infested trees, but their spread has been very slow.

Family Lonchaeidae
Lonchaeids

Adults of this family are shiny black and about 5 to 6 mm long. The larvae are very small and are covered by minute spines. These flies act mostly as scavengers or as predators on other insects. *Lonchaea polita* Say has been reared from bark-beetle infested wood. *L. corticis* Taylor has been recorded as an important parasite of the white pine weevil *(762)*.

Family Drosophilidae
Vinegar Flies

These are the flies that are so often seen around spoiled fruit, slime fluxes, and fungi. Usually yellowish except for black markings on the abdomen, adults seldom exceed 5 mm in length. Few if any species are of importance as enemies of forest, shade, or ornamental trees. There is a possibility, however, that certain species are involved in the transmission of the oak wilt fungus, *Ceratocystis fagacearum* (Bretz) Hunt *(507)*. Members of the genus *Drosophila* are very important in the field of genetics research.

Family Chloropidae
Chloropid Flies

These flies are small to very small with numerous clothing hairs and some bristles. Some species are brightly colored with yellow and black. The larvae of

certain species parasitize or prey on other insects; others have been found feeding in the seeds and cones of conifers. Adults of the genus *Hippelates* are attracted to the eyes of humans and of other animals, and are very annoying. Certain species are also reported to transmit yaws and pinkeye. *Gaurax apicalis* Malloch, *Oscinella coxendix* (Fitch), and *Hippelates* sp. have been reared from the leaders of eastern white pine infested by the white pine weevil *(762)*.

Family Agromyzidae
Leafminer Flies

These flies are very small and light or dark colored *(449)*. The body covering ranges from sparse bristles to dense hairs. The larvae are plant feeders; some mine the cambium, but the majority mine the leaves.

Larvae of the genus *Phytobia* feed in the cambium of living trees, making long, thin, gradually widening mines (fig. 215). These mines sometimes originate in the top of the tree and extend all the way to the base and into the roots. They cause defects known as pitch-ray flecks. Heavily infested logs may be rendered unfit for some uses.

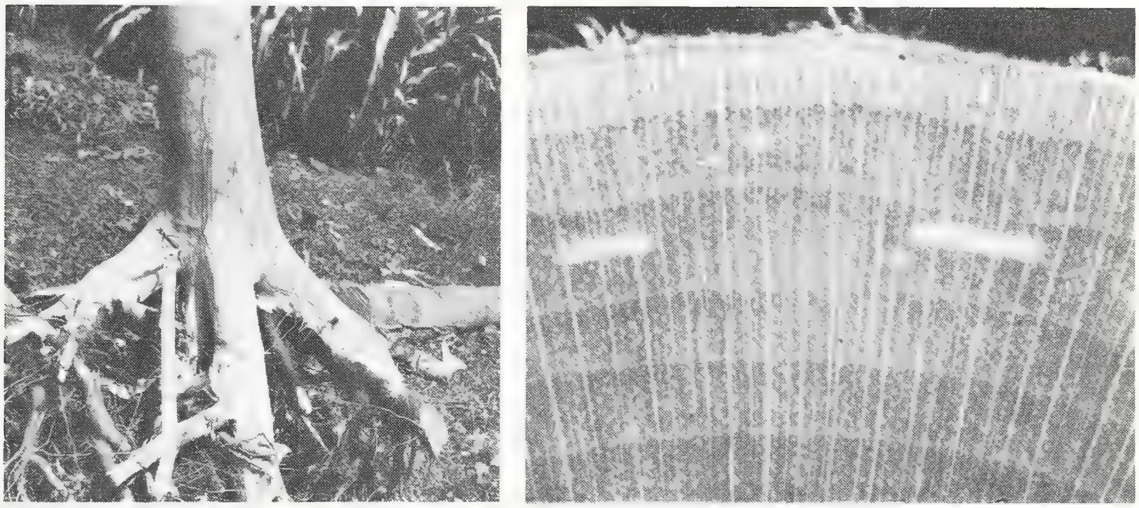

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Figure 215.—Cambium miner work: left, streaklike, longitudinal mines on trunk and roots of infested trees; right, pitch-ray flecks in the wood.

Phytobia setosa (Loew), the **red maple cambium borer**, attacks red and sugar maples *(523)*. Adults are small and dark colored. The larvae are opaque white and about 16 mm long. *P. pruinosa* (Coquillett) infests cherry, maple, and sweet and river birches. Adults are about 3 to 4 mm long; the larvae are up to 30 mm long. This species apparently lays its eggs in the forks of branches near the tops of trees and the larvae tunnel all the way down into the roots. *P. amelanchieris* (Greene), the **amelanchier twig borer**, attacks serviceberry, and *P. pruni* (Grossenbacher) attacks cherry.

The **native holly leafminer**, *Phytomyza ilicicola* Loew, is a serious pest of American holly in the Eastern United States. The adult is a small, grayish-black fly about 2.5 mm long. The female punctures leaves with her ovipostor and feeds on the juices exuding from the wounds. She also deposits eggs in the undersurfaces of leaves in punctures made near the midrib. The larvae mine the tissues between the leaf surfaces. The mine is hairlike at first but gradually widens as the larva continues to grow. Eventually it becomes blotchlike (fig. 216). Heavily infested leaves become unsightly and usually drop prematurely. Leaves damaged by feeding punctures become roughened, twisted, and stunted. The winter is spent as second

or third instars or as pupae in the mine *(705)*. Pupation occurs from early March to early April and the adults emerge from mid-May to late June. There is one generation per year.

Courtesy Conn. Agric. Exp. Stn.

Figure 216.—Injury by the native holly leafminer, *Phytomyza ilicicola*: left, undamaged leaves; right, mined leaves.

Several other members of the family also mine the leaves or produce galls on their hosts. *Japanagromyza viridula* (Coquillett) produces blotch mines in the leaves of red oak; *Hexomyza schineri* (Giraud) causes the formation of slight swellings on the smaller twigs of poplar; *H. tiliae* (Couden) produces swellings about 1 cm long on the twigs of basswood; *Nemorimyza posticata* (Meigen) produces blotch mines in the leaves of sweetgum; and *Trilobomyza pleuralis* (Malloch) produces blotch mines on catalpa.

Family Anthomyiidae
Anthomyiids

Members of this family are quite similar in appearance to those of the family Muscidae. The maggots vary in habits; some feed on the roots of plants, some are scavengers, and others are parasites of other insects. The **seedcorn maggot**, *Hylemya platura* (Meigen), damaged redcedar seedlings in a forest nursery in Tennessee *(1291)*. In this case, the larvae chewed through the bark of the main stem just below the ground line and fed on the roots. Large numbers of seedlings were killed.

Family Muscidae
House Flies, Stable Flies, and Allies

Flies of this family vary in length from 2 to 12 mm. Some are yellowish or black, but the majority are gray or brown. There are several economically important species, such as the well-known **house fly**, *Musca domestica* L., and the stable fly, *Stomoxys calcitrans* (L.). Tsetse flies, which transmit the organisms responsible for

sleeping sickness and other diseases, are native to Africa and do not occur in this country. A number of species in the genus *Muscina* are parasites of various species of Coleoptera.

Family Hippoboscidae
Louse Flies

Louse flies may be winged or wingless. Many look like lice. The body is flat and leathery-looking, and the legs are short, strong, and broadly separated by the sternum. The tarsi are short and armed with strong claws, and the abdomen is saclike. All species feed on birds and mammals. The best known member of the family is the **sheep ked**, *Melophagus ovinus* (L.), an important parasite of sheep. Other important species are *Icosta americana* (Leach)—parasitizes grouse, hawks, and owls; *Olfersia fumipennis* (Sahlberg)—attacks the bald eagle; species of *Ornithoica* and *Ornithomyia*—feed on various small birds; and species of *Lipoptena*—parasitize deer.

Family Calliphoridae
Blow Flies

Blow flies have metallic blue, green, or yellow bodies and are usually about the size of house flies. The arista of the antenna is plumose at the tip and the hindmost posthumeral bristle is almost always longer than the presutural bristle. In the maggots, the posterior spiracles are flush. A few species are economic pests, but the majority serve a useful purpose in helping to rid the landscape of such undesirable materials as dead animal bodies and animal excrement.

The **screwworm**, *Cochliomyia hominivorax* (Coquerel), a long-time pest of livestock in the Southwest, was first recorded from the Southeastern States in 1933. Since then, or until its eradication from the region through the mass release of sexually sterile males flies *(735)*, it caused tremendous losses to livestock. Big game, such as deer, and smaller animals, such as raccoons, rabbits, and opossums, have also been attacked and injured. The female deposits up to 300 eggs around wounds; the maggots feed on the tissues, and produce foul-smelling wounds. This attracts additional flies and compounds the infestation. Heavily infested animals may die within a few weeks unless the maggots are killed and the wounds treated.

Other blow flies occasionally attacking living animals include: *Phaenicia sericata* (Meigen), the **greenbottle fly**; the **black blow fly**, *Phormia regina* (Meigen); and the **secondary screwworm**, *C. macellaria* (F.). They also oviposit on wounds or sores. Larvae of the genus *Protocalliphora* are bloodsucking parasites of nestlings.

Family Sarcophagidae
Flesh Flies

Larvae of this family feed on a wide variety of foods. A number of species are scavengers, feeding on dead insects, dung, and other decaying materials. Some species are parasitic in various insects. Adults are 6 to 12 mm long, the sides of the face are hairy, the aristae of the antennae are feathery for about half their length, there are three black stripes on the thorax, and the abdomen is checkered. The larvae have their posterior spiracles located in a pit.

Sarcophaga aldrichi Parker, an important parasite of the forest tent caterpillar, occurs in southern Canada and from New England to the Lake States and Southern Appalachians. It significantly suppresses forest tent caterpillar outbreaks in the Lake States. Living young are normally deposited on cocoons and the larvae feed as scavengers on the prepupae or pupae inside the cocoons *(576)*. Full-grown larvae are about 13 mm long. The adults are strong, active fliers; during tent caterpillar outbreaks, they may occur in enormous numbers, swarming over everything,

livestock and people included. During intervals between outbreaks, the species is hard to find. In the Southern States, the related species, *S. houghi* Aldrich, parasitizes the forest tent caterpillar and elm spanworm.

Family Tachinidae
Tachina Flies

The family Tachinidae contains many of the most important species of insect parasites. All species appear to be internal parasites of many kinds of insects, especially Lepidoptera, but also various species of Coleoptera, Hemiptera, Orthoptera, and Hymenoptera *(1049)*.

Tachinid flies look very much like house flies but many differ in having an entirely bare arista; however, the arista on some species may be pubescent or as plumose as that of house flies. The maggots are clothed with minute spinules, and the posterior spiracles are flush with or raised from the adjacent area.

The majority of species are oviparous, but a few give birth to living young. Eggs are deposited on the skin of the host, on leaves or other parts of plants on which their hosts feed, or on the soil. Living young are deposited on or under the skin of the host, on leaves and other parts of plants frequented by their hosts, or on the ground. The number of generations per year varies from 1 to 10, depending on species and climate.

A large number of native species and a few introduced species parasitize various native and introduced species of eastern forest insects. More than 125 species have been recorded attacking lepidopterous larvae in this country *(1062, 1063)*. A few of the more important introduced species are discussed here.

Compsilura concinnata (Meigen) (fig. 217) was imported against the gypsy and browntail moths early in this century. It is now widely distributed throughout most of the Northeast and in southeastern Canada where it attacks at least 200 species of Lepidoptera. Parasitization of the gypsy moth averages from 10 to 50 percent in

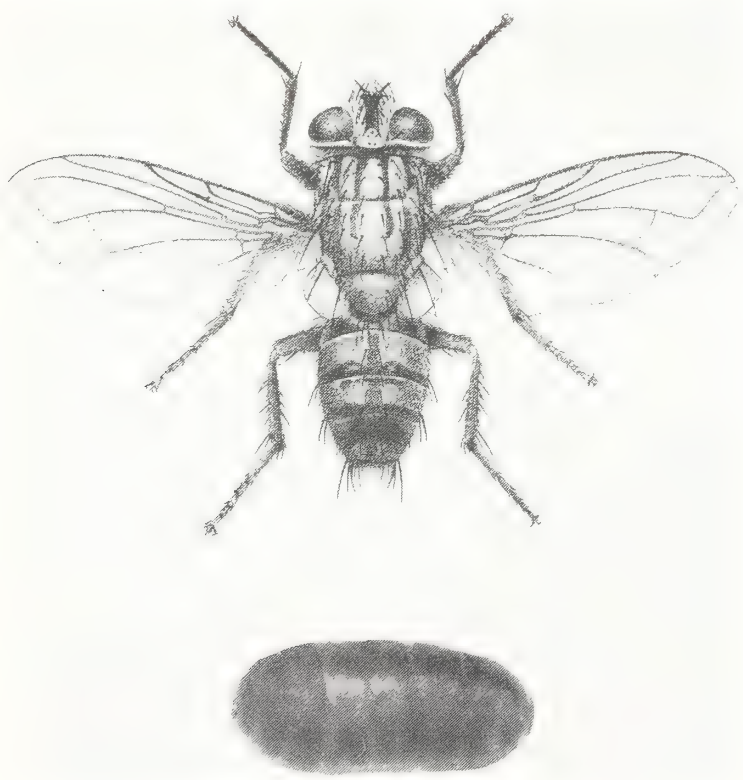

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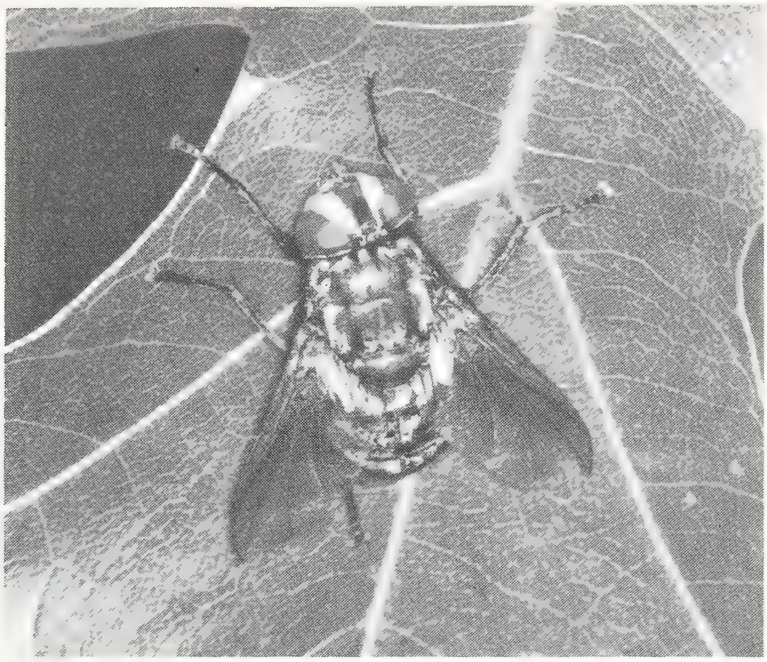
Figure 217.—Adult and puparium of *Compsilura concinnata*, a parasite of the gypsy moth and other defoliators.

much of the infested area. Even higher percentages are recorded in browntail and satin moth infestations *(173, 269, 328, 1262)*.

Blepharipa pratensis (Meigen) (fig. 218), a parasite of the gypsy moth, was imported and became established by 1911. In most of the areas where it occurs, it parasitizes from 5 to 25 percent of the gypsy moth population. As far as known, it confines its attack to the gypsy moth in this country, whereas in Europe it has several lepidopterous hosts. Its life history and habits are discussed *(173)*.



Courtesy P. Godwin, Hamden, Conn.

Figure 218.—Adult of *Blepharipa pratensis*, a parasite of the gypsy moth and other defoliators.

Parasetigena silvestris (Robineau-Desvoidy) and *Exorista larvarum* (L.) were imported against the gypsy moth from 1924 to 1933. *P. silvestris*, a single-brooded species, is probably the most important parasite of the nun moth in Europe. *E. larvarum*, a multibrooded species, attacks about 45 different hosts in Europe. Both species are now important parasites of the gypsy moth through the generally infested area in the United States. *E. larvarum* is also a parasite of the satin moth and browntail moth in this country.

Two species, *Townsendiellomyia nidicola* (Townsend) and *Carcelia laxifrons* Villeneuve, were imported against the browntail moth early in this century. *T. nidicola* quickly spread throughout the infested area. It has frequently parasitized an average of 17 percent of overwintering browntail moth larvae. *C. laxifrons* also occurs throughout the infested area. Unfortunately, it parasitizes a very low percentage of the population.

Chaetexorista javana Brauer & Bergenstamm, a native of Japan, was imported against the oriental moth in 1929 and 1930. As early as 1933, parasitism in the infested area around Boston, Mass., averaged 60 percent. *Erynniopsis antennata* Rondani, a native of Europe, has been successfully introduced into California against the European elm leaf beetle. Colonies have also been liberated against the beetle along the Atlantic Seaboard but without success. *Palexorista bohemica* (Mesnil), a native of Europe, was successfully introduced into Canada against the European spruce sawfly during the thirties and forties. This is probably the same species that was introduced into the United States around 1906 as *P. inconspicua*

(Meigen) against the gypsy moth, browntail moth, and redheaded pine sawfly *(328)*. It was recovered at gypsy moth colonization sites for several years thereafter, but it apparently did not become permanently established. It probably occurs now in northern Maine as a result of spread from New Brunswick and Quebec, where it appears to be one of the most effective parasites introduced against the European spruce sawfly.

Literature Cited

1. Abdullah, M. 1973. Larvae of the families of Coleoptera: a bibliographical survey; addenda et corrigenda I. Coleopt. Bull. 27(4):187-191.
2. Abrahamson, L. P., and D. M. Norris. 1966. Symbiotic interrelationships between microbes and ambrosia beetles. I. The organs of microbial transport and perpetuation of *Xyloterinus politus*. Ann. Entomol. Soc. Am. 59(5):877-880.
3. Acciavatti, R. E., and J. B. Simeone. 1976. The occurrence of anobiid species in a northern hardwood forest and the emergence, flight and host selection behavior of *Ptilinus ruficornis* (Say) (Coleoptera: Anobiidae). *In* Organismen und Holz: Internationales Symposium Berlin-Dahlem 1975. p. 419-427. [Suppl. Mater. und Org., Heft 3.] Gunther Becker and Walter Liese, eds. Duncker & Humblot, Berlin.
4. Aldrich, R. C., W. F. Bailey, and R. C. Heller. 1959. Large scale 70 mm photography techniques and equipment and their application to a forest sampling problem. Photogramm. Eng. 25(5):747-754.
5. Aldrich, R. C., and A. T. Drooz. 1967. Estimated Fraser fir mortality and balsam woolly aphid infestation trend using aerial color photography. For. Sci. 13:300-313.
6. Aldrich, R. C., R. C. Heller, and W. F. Bailey. 1958. Observation limits for aerial sketch-mapping southern pine beetle damage in the Southern Appalachians. J. For. 56(3): 200-202.
7. Alexander, R. D.1957. The taxonomy of the field crickets of the eastern United States (Orthoptera: Gryllidae: Acheta). Ann. Entomol. Soc. Am. 50(6):584-602.
8. Allen, D. C. 1972. Insect parasites of the saddled prominent, *Heterocampa guttivitta* (Lepidoptera: Notodontidae), in the Northeastern United States. Can. Entomol. 104(10): 1609-1622.
9. Allen, D. C. 1976. Biology of the green-striped mapleworm, *Dryocampa rubicunda* (Lepidoptera: Saturniidae) in the Northeastern United States. Ann. Entomol. Soc. Am. 69(5):857-862.
10. Allen, D. C. 1979. Observations on biology and natural control of the orangehumped mapleworm, *Symmerista leucitys* (Lepidoptera: Notodontidae), in New York. Can. Entomol. 111:703-708.
11. Allen, W. H. 1959. The Japanese weevil, *Pseudoencorhinus bifasciatus* (Roelofs). J. Econ. Entomol. 52:586-587.
12. Amburgey, T. L. 1971. Hazards of earthfill construction. Pest Control 39(8):34-36.
13. Amman, G. D. 1962. Seasonal biology of the balsam woolly aphid on Mt. Mitchell, North Carolina. J. Econ. Entomol. 55(1):96-98.
14. Anderson, D. M., chairman, Committee on Common Names of Insects. 1975. Common names of insects. rev. Entomol. Soc. Am., Spec. Publ. 75-1, 37 p.
15. Anderson, J. F. 1976. Egg parasitoids of defoliating Lepidop-

tera. *In* Perspectives in forest entomology. p. 233-249. J. F. Anderson and H. K. Kaya, eds. Academic Press, New York.

16. Anderson, J. F. 1982. The gypsy moth. Front. Plant Sci. 32(3):1-8.
17. Anderson, J. F., R. P. Ford, J. D. Kegg, and J. H. Risley. 1976. A report to the 1975 Eastern Plant Board. The red pine scale in North America. Conn. Agric. Exp. Stn. Bull. 765, 6 p.
18. Anderson, J. F., and H. K. Kaya. 1977. Field and laboratory biology of *Symmerista canicosta*. Ann. Entomol. Soc. Am. 71:137-142.
19. Anderson, J. F., and R. M. Weseloh. 1981. The gypsy moth in Connecticut. 1. Defoliation 1975-1980. 2. Review of biological control studies. Conn. Agric. Exp. Stn. Bull. 797, 25 p.
20. Anderson, L. D., and C. S. Papp. 1961. The larger elm leaf beetle, *Monocesta coryli* (Say): (Coleoptera: Chrysomelidae). Proc. Entomol. Soc. Wash. 63(3):203-207.
21. Anderson, R. F. 1960. Forest and shade tree entomology. 428 p. John Wiley & Sons, Inc., New York.
22. Anderson, R. L., and W. M. Hoffard. 1978. Fusarium canker-ambrosia beetle complex on tulip poplar in Ohio. U.S. Dep. Agric., Agric. Res. Serv., Plant Dis. Rep. 62:751.
23. Anderson, W. H. 1947. Larvae of some genera of Anthribidae (Coleoptera). Ann. Entomol. Soc. Am. 40(3):489-517.
24. Anderson, W. H. 1952. Larvae of some genera of Cossoninae (Coleoptera: Curculionidae). Ann. Entomol. Soc. Am. 45(2):281-309.
25. Andreadis, T. G., N. R. Dubois, R. M. Weseloh, R. E. B. Moore, J. F. Anderson, and F. B. Lewis. 1982. Aerial spray tests with *Bacillus thuringiensis* for control of the gypsy moth in Connecticut. Conn. Agric. Exp. Stn. Bull. 807, 5 p.
26. Arnaud, P. H., Jr. 1978. A host-parasite catalog of North American Tachinidae (Diptera). U.S. Dep. Agric., Sci. and Educ. Admin. Misc. Publ. 1319, 860 p.
27. Arnett, R. H., Jr. 1963. The beetles of the United States: a manual for identification. 1112 p. Am. Entomol. Inst., Ann Arbor, Mich.
28. Asquith, D. 1949. Two generations of European fruit lecanium in southern Pennsylvania. J. Econ. Entomol. 42(5):853.
29. Atwood, C. E. 1961. Present status of the sawfly family Diprionidae (Hymenoptera) in Ontario. Proc. Entomol. Soc. Ont. 91:205-215.
30. Atwood, C. E., and O. Peck. 1943. Some native sawflies of the genus *Neodiprion* attacking pines in eastern Canada. Can. J. Res., Sect. D, 21(5):109-144.
31. Averill, R. D., L. F. Wilson, and R. F. Fowler. 1982. Impact of the redheaded pine sawfly (Hymenoptera: Diprionidae) on young red pine plantations. Great Lakes Entomol. 15:65-91.
32. Avidov, Z., and I. Harpaz. 1969. Plant pests of Israel. 549 p. Israel Univ. Press., Jerusalem.
33. Baccetti. B. 1960. Le cocciniglie Italiane della Cupressaceae. Estratto Redia 45:23-111.
34. Baer, R. G. 1978. A morphological and systematic study of the first and second instars of the Kermesidae in the Nearctic Region, Ph.D. diss. Dep. Entomol., Va. Polytech. Inst. & State Univ., Blacksburg. 192 p.
35. Baerg, W. J. 1959. The black widow spider and five other venomous spiders in the United States. Ark. Agric. Exp. Stn. Bull. 608, 43 p.
36. Baerg, W. J. 1961. Scorpions: biology and effect of their venom. Ark. Agric. Exp. Stn.

Bull. 649, 34 p.

37. Bailey, J. W. 1928. The Chilopoda of New York State with notes on the Diplopoda. N.Y. State Mus. Bull. 276:5-50.
38. Bailey, S. F. 1940. The distribution of injurious thrips in the United States. J. Econ. Entomol. 33(1):133-136.
39. Baker, E. W., and G. W. Wharton. 1952. An introduction to acarology. 465 p. The Macmillan Co., New York.
40. Baker, H. 1933. The obscure scale on the pecan and its control. U.S. Dep. Agric. Circ. 295, 20 p.
41. Baker, J. M. 1963. Ambrosia beetles and their fungi, with particular reference to *Platypus cylindrus* Fab. *In* Symbiotic associations. 13th Symp. Soc. Gen. Microbiol., Royal Inst., London, April 1963, p. 232-265. [Published for Soc. Gen. Microbiol. at Cambridge Univ. Press, Cambridge.]
42. Baker, W. L. 1941. Effect of gypsy moth defoliation on certain forest trees. J. For. 39(12):1017-1022.
43. Baker, W. L. 1948. Transmission by leaf hoppers of the virus causing phloem necrosis of American elm. Science 108(2803):307-308.
44. Baker, W. L. 1949. Studies on the transmission of the virus causing phloem necrosis of American elm, with notes on the biology of its insect vector. J. Econ. Entomol. 42(5):729-732.
45. Baker, W. L. 1972. Eastern forest insects. U.S. Dep. Agric., Misc. Publ. 1175, 642 p.
46. Balch, R. E. 1946. The spruce budworm and forest management in the Maritime Provinces. Dom. Can. Dep. Agric., Sci. Serv., Div. Entomol., Proc. Publ. 60, 7 p.
47. Balch, R. E. 1952. Studies of balsam woolly aphid, *Adelges piceae* (Ratz.) (Homoptera: Phylloxeridae) and its effects on balsam fir, *Abies balsamea* (L.) Mill. Can. Dep. Agric. Publ. 867, 76 p.
48. Balch, R. E. 1960. The approach to biological control in forest entomology. Can. Entomol. 92(4):297-310.
49. Balch, R. E., and F. T. Bird. 1944. A disease of the European spruce sawfly, *Gilpinia hercyniae* (Htg.), and its place in natural control. Sci. Agric. 25(2):65-80.
50. Balch, R. E., and R. G. Mitchell. 1967. Balsam woolly aphid: *Adelges (= Dreyfusia, Chermes) piceae* (Ratz.). *In* Important forest insects and diseases of mutual concern to Canada, the United States and Mexico. A. G. Davidson and R. M. Prentice, eds. Can. Dep. For. & Rural Dev. Publ. 1180, p. 70-74.
51. Balch, R. E., F. E. Webb, and J. J. Fettes. 1955-56. The use of aircraft in forest insect control. For. Abstr. Part 1, 16(4): 453-465, 1955; Part II, 17(1):3-9, 1956; Part III, 17(2): 149-159, 1956.
52. Balduf, W. V. 1928. Observations on the buffalo tree hopper *Ceresa bubalus* Fabr. (Membracidae: Homoptera), and the bionomics of an egg parasite, *Polynema striaticorne* Girault (Mymaridae, Hymenoptera). Ann. Entomol. Soc. Am. 21(3):419-435.
53. Balsbaugh, E. U., Jr., and K. L. Hays. 1972. The leaf beetles of Alabama (Coleoptera: Chrysomelidae). Ala. Agric. Exp. Stn., Auburn Univ. Bull. 441, 223 p.
54. Baranowski, R. M. 1958. Notes on the biology of the royal palm bug, *Xylastrodoris luteolus* Barber (Hemiptera: Thaumastocoridae). Ann. Entomol. Soc. Am. 51(6): 547-551.
55. Barber, L. R. 1979. Evaluation of two carbofuran soil incorporating systems. U.S. Dep.

Agric. For. Serv., Southeast. Area. For. Insect and Dis. Manage. Rep. 79-1-17, 14 p.

56. Barnes, W., and J. McDunnough. 1918. Article V. Life histories of North American species of the genus *Catocala*. Bull. Am. Mus. Nat. Hist. 38:147-177.

57. Barras, S. J., D. F. Clower, and R. G. Merrifield. 1967. Control of the Nantucket pine tip moth on loblolly pine with systemic insecticides in Louisiana. J. Econ. Entomol. 60(1):185-190.

58. Barras, S. J., and D. M. Norris. 1969. Bionomics of *Eucosma monitorana* (Lepidoptera: Tortricidae) attacking red pine cones in Wisconsin. Ann. Entomol. Soc. Am. 62(6): 1284-1290.

59. Barry, J. W., and W. M. Ciesla. 1981. Managing drift in forest spray operations. Aerial Applicator 19(9):8-9,12,17.

60. Bartelt, R. J., R. L. Jones, and H. M. Kulman. 1982. Evidence for a multicomponent sex pheromone in the yellowheaded spruce sawfly. J. Chem. Ecol. 8:83-94.

61. Bartelt, R. J., R. L. Jones, and H. M. Kulman. 1982. Hydrocarbon components of the yellowheaded spruce sawfly sex pheromone: a series of (z,z)-9,19 dienes. J. Chem. Ecol. 8:95-114.

62. Barter, G. W. 1957. Studies of the bronze birch borer, *Agrilus anxius* Gory, in New Brunswick. Can. Entomol. 89(1):12-36.

63. Barter, G. W. 1965. Survival and development of the bronze poplar borer *Agrilus liragus* Barter & Brown (Coleoptera: Buprestidae). Can. Entomol. 97(10): 1063-1068.

64. Bartlett, B. R., and D. W. Clancy. 1972. The Comstock mealybug in California and observations on some of its natural enemies. J. Econ. Entomol. 65(5):1329-1332.

65. Basham, H. G. 1970. Wilt of loblolly pine inoculated with blue-stain fungi of the genus *Ceratocystis*. Phytopathology 60:750-754.

66. Baskerville, G. L., R. M. Belyea, C. A. Miller, E. G. Ketella, K. B. Marshall, and I. W. Varty. 1975. The spruce budworm. For. Chron. 51:1-26.

67. Batra, L. R. 1963. Ecology of ambrosia fungi and their dissemination by beetles. Trans. Kans. Acad. Sci. 66(2): 213-236.

68. Batra, L. R. 1968. Ambrosia fungi: a taxonomic revision, and nutritional studies of some species. Mycologia 59(6): 976-1017.

69. Batzer, H. O., and A. R. Hastings. 1980. How to rate spruce-fir vulnerability to budworm in Minnesota. U.S. Dep. Agric., For. Serv. How-To Leafl. [Unpaged.] North Cent. For. Exp. Stn., St. Paul, Minn.

70. Batzer, H. O., and A. R. Hastings. 1981. Rating spruce-fir stands for spruce budworm vulnerability in Minnesota. *In* Hazard-rating systems in forest pest management. Symp. Proc. U.S. Dep. Agric., For. Serv. Gen. Tech. Rep. WO-27, p. 105-108. Washington, D.C.

71. Batzer, H. O., and R. C. Morris. 1978. Forest tent caterpillar. U.S. Dep. Agric., For. Insect & Dis. Leafl. 9, 8 p.

72. Beal, J. A. 1932. Control of the turpentine borer in the naval stores region. U.S. Dep. Agric. Circ. 226, 19 p.

73. Beal, J. A. 1933. Temperature extremes as a factor in the ecology of the southern pine beetle. J. For. 31(3):329-336.

74. Beal, J. A., W. Haliburton, and F. B. Knight. 1952. Forest insects of the Southeast: with special reference to species occur-

ring in the Piedmont plateau of North Carolina. Duke Univ. Sch. For. Bull. 14, 168 p.

75. Beal, J. A., and K. B. McClintick. 1943. The pales weevil in southern pine. J. Econ. Entomol. 36(5):792-794.

76. Beal, J. A., and C. L. Massey. 1945. Bark beetles and ambrosia beetles (Coleoptera: Scolytidea): with special reference to species occurring in North Carolina. Duke Univ. Sch. For. Bull. 10, 178 p.

77. Beal, R. H. 1967. Formosan invader. Pest Control 35(2):13-17.

78. Bean, J. L., and H. O. Batzer. 1956. A spruce budworm risk-rating for the spruce-fir types in the Lake States. U.S. Dep. Agric. For. Serv., Lake States For. Exp. Stn., Tech. Notes 453, 2 p.

79. Bean, J. L., and P. A. Godwin. 1955. Description and bionomics of a new red pine scale, *Matsucoccus resinosae*. For. Sci. 1(2):164-176.

80. Becker, G. C., Jr., and D. M. Benjamin. 1964. Biology of the Swaine jack-pine sawfly in Wisconsin. Can. Entomol. 96(4):589-599.

81. Becker, G. C., and D. M. Benjamin. 1967. The biology of *Neodiprion nigroscutum* (Hymenoptera: Diprionidae) in Wisconsin. Can. Entomol. 99(2):146-159.

82. Becker, G. C., R. C. Wilkinson, and D. M. Benjamin. 1966. The taxonomy of *Neodiprion rugifrons* and *N. dubiosus* (Hymenoptera: Tenthredinoidea: Diprionidae). Ann. Entomol. Soc. Am. 59:173-178.

83. Becker, W. B. 1938. Leaf-feeding insects of shade trees. Mass. Agric. Exp. Stn. Bull. 353, p. 1-78, 81-83.

84. Behre, C. E., A. C. Cline, and W. L. Baker. 1936. Silvicultural control of the gypsy moth. Mass. For. & Park Assoc. Bull. 157, 16 p.

85. Belanger, R. P. [1981]. Silvicultural guidelines for reducing losses to the southern pine beetle. *In* The southern pine beetle. R. C. Thatcher, J. L. Searcy, J. E. Coster, and G. D. Hertel, eds. U.S. Dep. Agric. For. Serv. and Sci. and Educ. Admin. Tech. Bull. 1631, p. 165-177.

86. Belanger, R. P., and B. F. Malac. 1980. Silviculture can reduce losses from the southern pine beetle. U.S. Dep. Agric., Comb. For. Pest Res. & Dev. Program, Agric. Handb. 576, 17 p.

87. Belanger, R. P., E. A. Osgood, and G. E. Hatchell. 1979. Stand, soil and site characteristics associated with southern pine beetle infestations in the southern Appalachians. U.S. Dep. Agric. For. Serv., Res. Pap. SE-198, 7 p. Southeast. For. Exp. Stn., Asheville, N.C.

88. Bellinger, P. F. 1954. Studies of soil fauna with special reference to the Collembola. Conn. Agric. Exp. Stn. Bull. 583, 67 p.

89. Belyea, R. M. 1952. Death and deterioration of balsam fir weakened by spruce budworm defoliation in Ontario. Part II. An assessment of the role of associated insect species in the death of severely weakened trees. J. For. 50(10):729-738.

90. Benedict, W. V. 1959. Every forester has a stake in forest insect spraying. J. For. 57(4): 245-249.

91. Benhem, G. S., Jr. 1974. A synopsis of the obligate and facultative insect parasite nematodes. J. Invert. Pathol. 24:263-270.

92. Benjamin, D. M. 1955. The biology and ecology of the red-headed pine sawfly. U.S. Dep. Agric., Tech. Bull. 1118, 57 p.

93. Bennett, F. D., and S. W. Brown. 1958. Life history and sex determination in the di-

aspine scale, *Pseudaulacaspis pentagona* (Targ.) (Coccoidea). Can. Entomol. 90(6):317-324.

94. Bennett, W. H. 1966. Pupal morphology of *Exoteleia chillicotti* Freeman (Lepidoptera, Gelechiidae). Proc. Entomol. Soc. Wash. 68(3):181-183.

95. Bennett, W. H. 1967. The Texas leaf-cutting ant. U.S. Dep. Agric. For. Serv., For. Pest Leafl. 23 rev., 4 p.

96. Bergold, G. H. 1953. On the nomenclature and classification of insect viruses. Ann. N.Y. Acad. Sci., Artic. 3, 56: 495-516.

97. Berisford, C. W. 1974. Comparisons of adult emergence periods and generations of the pine tip moths, *Rhyacionia frustrana* and *R. rigidana*. Ann. Entomol. Soc. Am. 67(4):666-668.

98. Berisford, C. W. [1981]. Natural enemies and associated organisms. *In* The southern pine beetle. R. C. Thatcher, J. L. Searcy, J. E. Coster, and G. D. Hertel, eds. U.S. Dep. Agric. For. Serv. and Sci. and Educ. Admin. Tech. Bull. 1631, p. 31-52.

99. Berisford, C. W. 1982. Pheromones of *Rhyacionia* spp.: identification, function, and utility. J. Ga. Entomol. Soc. 17(2d suppl.):23-30.

100. Berni, C. A., E. Bolza, and F. J. Christensen. 1979. South American timbers—the characteristics, properties, and uses of 190 species. 229 p. CSIRO, Div. Build. Res., Melbourne, Australia.

101. Beroza, M. 1976. Prospects for controlling gypsy moths and some other insects with sex pheromones. J. For. 74:146-150.

102. Berry, P. A. 1938. *Tetrastichus brevistigma* Gahan, a pupal parasite of the elm leaf beetle. U.S. Dep. Agric. Circ. 485, 12 p.

103. Berryman, A. A. 1972. Resistance of conifers to invasion by bark beetle fungus associates. Bio. Sci. 22:598-602.

104. Bess, H. A. 1961. Population ecology of the gypsy moth: *Porthetria dispar* L. (Lepidoptera: Lymantridae). Conn. Agric. Exp. Stn. Bull. 646, 43 p.

105. Bess, H. A., S. H. Spurr, and E. W. Littlefield. 1947. Forest site conditions and the gypsy moth. Harv. For. Bull. 22, 56 p.

106. Bierl, B. A., M. Beroza, and C. W. Collier. 1970. Potent sex attractant of the gypsy moth: its isolation, identification, and synthesis. Science 170(3953): 87-89.

107. Billings, R. F., and C. M. Bryant. 1982. Southern pine beetle field guide for hazard rating, prevention and control. Tex. For. Serv. Circ. 259, 24 p. College Station, Tex.

108. Billings, R. F., and C. Doggett. 1979. An aerial observer's guide to recognizing and reporting southern pine beetle spots. U.S. Dep. Agric., Agric. Handb. 560, 19 p.

109. Billings, R. F., and H. A. Pase III. 1979. A field guide for ground checking southern pine beetle spots. U.S. Dep. Agric., Agric. Handb. 558, 19 p.

110. Birch, M. C., ed. 1974. Pheromones. 495 p. North-Holland Publ. Co., Amsterdam & London; Am. Elsevier Publ. Co., Inc., New York.

111. Birch, M. C. 1978. Chemical communication in pine bark beetles. Am. Sci. 68:409-419.

112. Bird, F. T. 1953. The use of a virus disease in the biological control of the European pine sawfly, *Neodiprion sertifer* (Geoffr.). Can. Entomol. 85(12):437-446.

113. Bird, F. T. 1955. Virus diseases of sawflies. Can. Entomol. 87(3):124-127.

114. Bishopp, F. C. 1923. The puss caterpillar and the effects of its sting on man. U.S. Dep. Agric., Dep. Circ. 288, 14 p.

115. Blackman, M. W. 1919. Notes

on forest insects. II. Notes on several species of *Pityophthorus* breeding in the limbs and twigs of white pine. Psyche: J. Entomol. 26(5):134-142.

116. Blackman, M. W. 1928. The genus *Pityophthorus* Eichh. in North America: A revisional study of the Pityophthori, with descriptions of two new genera and seventy-one new species. Bull. N.Y. State Coll. For. at Syracuse Univ., Tech. Publ. 25, p. 5-184.

117. Blackman, M. W. 1931. A revisional study of the genus *Gnathotrichus* Eichhoff in North America. J. Wash. Acad. Sci. 21(12):264-276.

118. Blackman, M. W. 1931. A revisional study of the genus *Pseudopityophthorus* Sw. in North America. J. Wash. Acad. Sci. 21(10):223-236.

119. Blackman, M. W. 1934. A revisional study of the genus *Scolytus* Geoffroy *(Eccoptogaster* Herbst) in North America. U.S. Dep. Agric., Tech. Bull. 431, 31 p.

120. Blackman, M. W. 1938. The genus *Chramesus* LeConte in North America (Coleoptera: Scolytidae). J. Wash. Acad. Sci. 28(12):534-545.

121. Blackman, M. W. 1941. Bark beetles of the genus *Hylastes* Erichson in North America. U.S. Dep. Agric., Misc. Publ. 417, 27 p.

122. Blackman, M. W. 1942. Revision of the genus *Phloeosinus* Chapuis in North America (Coleoptera: Scolytidae). Proc. U.S. Natl. Mus. 92(3154):397-474.

123. Blackman, M. W. 1943. New genera and species of bark beetles of the subfamily Micracinae (Scolytidae: Coleoptera). Proc. U.S. Natl. Mus. 93(3165): 341-365.

124. Blais, J. R. 1960. Spruce budworm parasite investigations in the lower St. Lawrence and Gaspé regions of Quebec. Can. Entomol. 92(5):384-396.

125. Blais, J. R. 1964. Account of a recent spruce budworm outbreak in the Laurentides Park region of Quebec and measures for reducing damage in future outbreaks. For. Chron. 40:313-323.

126. Blais, J. R. 1965. Parasite studies in two residual spruce budworm *(Choristoneura fumiferana* (Clem.)) outbreaks in Quebec. Can. Entomol. 97(2):129-136.

127. Blais, J. R. 1981. Population trends of the spruce budworm and characteristics of outbreak. *In* Review of the spruce budworm outbreaks in Newfoundland—its control and forest management implications. J. Hudak and A. Raske, eds. Can. For. Serv. Inf. Rep. N-X-205, p. 22-24. Ste. Foy, Quebec.

128. Blatchley, W. S. 1910. An illustrated descriptive catalogue of the Coleoptera or beetles (exclusive of the Rhynchophora), known to occur in Indiana. 1386 p. Nature Publ. Co., Indianapolis.

129. Blatchley, W. S. 1920. Orthoptera of northeastern America: with especial reference to the faunas of Indiana and Florida. 784 p. Nature Publ. Co., Indianapolis.

130. Blatchley, W. S. 1926. Heteroptera or true bugs of eastern North America: with especial reference to the faunas of Indiana and Florida. 1116 p. Nature Publ. Co., Indianapolis.

131. Bletchly, J. D. 1960. The susceptibility of hardwoods to Lyctus powder-post beetles and methods of control. *In* Report of the seventh Commonwealth entomological conference 6-15 July 1960, p. 97-103. [Published by Commonw. Inst. Entomol., London.]

132. Bletchly, J. D. 1967. Insect and marine borer damage to timber and woodwork: recognition,

prevention and eradication. 88 p. H. M. Stationery Off., London.
133. Bliss, M., Jr., and W. H. Kearby. 1970. Notes on the life history of the pales weevil and northern pine weevil in central Pennsylvania. Ann. Entomol. Soc. Am. 63:731-734.
134. Bobb, M. L. 1965. Insect parasite and predator studies in a declining sawfly population. J. Econ. Entomol. 58(5):925-926.
135. Boethel, D. J., P. E. Schilling, and D. S. Babcock. 1980. Pecan carpenterworm: monitoring infestations in Louisiana. J. Ga. Entomol. Soc. 15:469-474.
136. Bolza, E., and W. G. Keating. 1972. African timbers—the properties, uses and characteristics of 700 species. 751 p. CSIRO, Div. Build. Res., Melbourne, Australia.
137. Bongberg, J. W. 1958. Forest insect surveys in the United States. Proc. 10th Int. Congr. Entomol. Montreal 4:193-200. [Aug. 17-25, 1956.]
138. Boratynski, K. 1961. A note on the species of *Asterolecanium* Targioni-Tozzetti, 1869 (Hymoptera: Coccoidea: Asterolecaniidae) on oak in Britain. Proc. Roy. Entomol. Soc. Lond., Ser. B Taon., Parts 1 & 2, 30:4-14.
139. Bořkovec, A. B. 1962. Sexual sterilization of insects by chemicals: eradication of harmful insects may be achieved with analogs of cancer chemotherapeutic agents. Science 137(3535): 1034-1037.
140. Borror, D. J., D. M. DeLong, and C. A. Triplehorn. 1981. An introduction to the study of insects. 5th ed. 827 p. Saunders College Publ., Philadelphia.
141. Böving, A. G., and A. B. Champlain. 1921. Larvae of North American beetles of the family Cleridae. Proc. U.S. Natl. Mus. 57(2323):575-649.
142. Böving, A. G., and F. C. Craighead. 1931. An illustrated synopsis of the principal larval forms of the order Coleoptera. Entomol. Am. (n.s.) 11(1-4): 1-351.
143. Boyne, J. V., and F. P. Hain. 1983. Effects of constant temperature, relative humidity, and simulated rainfall on development and survival of the spruce spider mite. Can. Entomol. 115:93-105.
144. Bracken, D. F. 1961. The external morphology of two eastern species of the genus *Anoplonyx* (Hymenoptera: Tenthredinidae), with special reference to *Anoplonyx luteipes* (Cresson). Can. Entomol. 93(7):573-593.
145. Bradley, J. C. 1930. A manual of the genera of beetles of America north of Mexico: keys for determination of the families, subfamilies, tribes, and genera of Coleoptera with systematic list of the genera and higher groups. 360 p. Daw, Illston and Co., Ithaca, N.Y.
146. Bramble, W. C., and E. C. Holst. 1940. Fungi associated with *Dendroctonus frontalis* in killing shortleaf pines and their effect on conduction. Phytopathology 30(11):881-899.
147. Braun, A. F. 1917. Nepticulidae of North America. Trans. Am. Entomol. Soc. 43(2):155-209.
148. Braun, A. F. 1963. The genus *Bucculatrix* in America north of Mexico (Microlepidoptera). Mem. Am. Entomol. Soc. 18, 208 p.
149. Bray, D. F. 1957. *Matsucoccus*. Sci. Tree Topics 2(4):10-13.
150. Brezner, J. 1960. Biology, ecology, and taxonomy of insects infesting acorns. Univ. Mo. Coll. Agric., Agric. Exp. Stn. Res. Bull. 726, 40 p.
151. Bright, D. E., Jr. 1963. Bark beetles of the genus *Dryocoetes* (Coleoptera: Scolytidae) in North America. Ann. Entomol. Soc. Am. 56(1):103-115.
152. Bright, D. E., Jr. 1968. Review

of the tribe Xyleborini in America north of Mexico (Coleoptera: Scolytidae). Can. Entomol. 100(12):1288-1323.

153. Bright, D. E., Jr. 1976. The bark beetles of Canada and Alaska (Coleoptera: Scolytidae). Insects and Arachnids of Canada, Part 2. Can. Dep. Agric. Publ. 1576, 241 p. Ottawa.

154. Bright, D. E., Jr. 1981. Taxonomic monograph of the genus *Pityophthorus* Eichhoff in North and Central America (Coleoptera: Scolytidae). Mem. Entomol. Soc. Can. 118, 378 p.

155. Brimley, C. S. 1938. The insects of North Carolina: being a list of the insects of North Carolina and their close relatives. 560 p. N.C. State Dep. Agric., Div. Entomol., Raleigh.

156. Britton, W. E. 1913. The appletree tent-caterpillar. Conn. Agric. Exp. Stn. Bull. 177, 20 p.

157. Britton, W. E. 1923. Guide to the insects of Connecticut. Part IV. the Hemiptera or sucking insects of Connecticut. State of Conn., State Geol. & Nat. Hist. Surv. Bull. 34, 807 p.

158. Brooks, F. E. 1923. Oak sapling borer, *Goes tesselatus* Haldeman. J. Agric. Res. 26(7):313-317.

159. Brooks, F. E. 1926. Life history of the hickory spiral borer, *Agrilus arcuatus* Say. J. Agric. Res. 33(4):331-338.

160. Brower, A. E. 1952. Arborvitae leaf miners (Yponomeutidae and Gelechiidae). *In* Important tree pests of the Northeast. p. 20-23. 2d ed. Committee on Tree Pest Leaflets, New England Section Society of American Foresters, ed. Evans Print Co., Concord, N.H.

161. Brower, A. E. 1974. A list of the Lepidoptera of Maine—Part 1. The Macrolepidoptera. Univ. Maine, LSA Exp. Stn. Tech. Bull. 66, 136 p.

162. Brown, C. E. 1962. The life history and dispersal of the Bruce spanworm, *Operophtera bruceata* (Hulst), (Lepidoptera: Geometridae). Can. Entomol. 94(10): 1103-1107.

163. Brown, N. R., and R. C. Clark. 1959. Studies of predators of the balsam woolly aphid, *Adelges piceae* (Ratz.) (Homoptera: Adelgidae) VI. *Aphidecta obliterata* (L.) (Coleoptera: Coccinellidae), an introduced predator in eastern Canada. Can. Entomol. 91(9):596-599.

164. Brown, N. R., and R. C. Clark. 1962. Studies of predators of the balsam woolly aphid, *Adelges piceae* (Ratz.) (Homoptera: Adelgidae). X. Field identification of *Laricobius erichsonii* Rosen. (Coleoptera: Derodontidae). Can. Entomol. 94(2): 191-193.

165. Brues, C. T., A. L. Melander, and F. M. Carpenter. 1954. Classification of insects: keys to the living and extinct families of insects, and to the living families of other terrestrial arthropods. Harv. Coll. Bull. Mus. Comp. Zool. 108, 917 p.

166. Buchanan, L. L. 1946. The Japanese weevil, *Pseudoencorhinus bifasciatus,* in America *(P. setosus* of American records, not Roelofs) (Coleoptera: Curculionidae). Bull. Brooklyn Entomol. Soc. 41:143.

167. Buchanan, W. D. 1941. Experiments with an ambrosia beetle, *Xylosandrus germanus* (Blfd.). J. Econ. Entomol. 34(3): 367-369.

168. Buchanan, W. D. 1958. The small oak bark beetle transmits the oak wilt disease. J. For. 56(6):414-415.

169. Buchanan, W. D. 1960. Biology of the oak timberworm, *Arrhenodes minutus*. J. Econ. Entomol. 53:510-513.

170. Buckner, C. H. 1966. The role of vertebrate predators in the bi-

ological control of forest insects. Annu. Rev. Entomol. 11:449-470.

171. Bullington, S. W. 1978. A revision of the Kermesini in North America. M.S. Thesis. Dep. Entomol., Va. Polytech. Inst. & State Univ., Blacksburg. 211 p.

172. Buren, W. F. 1972. Revisionary studies on the taxonomy of the imported fire ants. J. Ga. Entomol. Soc. 7:1-26.

173. Burgess, A. F. 1929. Imported insect enemies of the gypsy moth and the brown-tail moth. U.S. Dep. Agric., Tech. Bull. 86, 148 p.

174. Burgess, A. F., and S. S. Crossman. 1927. The satin moth, a recently introduced pest. U.S. Dep. Agric. Bull. 1469, 23 p.

175. Burks, B. D. 1943. The North American parasitic wasps of the genus *Tetrastichus:* a contribution to biological control of insect pests. Proc. U.S. Natl. Mus. 93(3170):508-608.

176. Burns, D. P., and D. E. Donley. 1970. Biology of the tuliptree scale, *Toumeyella liriodendri*. Ann. Entomol. Soc. Am. 63(1):228-235.

177. Burns, D. P., and L. P. Gibson. 1968. The leaf-mining weevil of yellow-poplar. Can. Entomol. 100(4): 421-429.

178. Busck, A. 1915. The European pine-shoot moth: a serious menace to pine timber in America. U.S. Dep. Agric. Bull. 170. 11 p.

179. Bushland, R. C. 1960. Male sterilization for the control of insects. *In* Advances in pest control research, vol. 3. p. 1-25. R. L. Metcalf, ed. Interscience Publ., Inc., New York and London.

180. Bushland, R. C., and D. E. Hopkins. 1951. Experiments with screw-worm flies sterilized by X-rays. J. Econ. Entomol. 44(5):725-731.

181. Bushland, R. C., and D. E. Hopkins. 1953. Sterilization of screw-worm flies with X-rays and gamma-rays. J. Econ. Entomol. 46(4):648-656.

182. Butterworth, J. H., and E. D. Morgan. 1971. Investigations of the locust feeding inhibition of the seeds of the neem tree, *Azadirachta indica*. J. Insect Physiol. 17:969-977.

183. Calcotte, V. R. 1975. Pecan weevil: feeding and initial oviposition as related to nut development. J. Econ. Entomol. 68:4-6.

184. Calcotte, V. R., and D. E. Hyder. 1981. Pecan weevil performance for various pecan cultivars. J. Econ. Entomol. 74:223-226.

185. Callahan, J. T. 1977. Resource utilization by colonial Lepidoptera defoliators. *In* The role of arthropods in forest ecosystems. p. 30-34. W. J. Mattson, ed. Springer-Verlag, New York-Heidelberg-Berlin.

186. Cameron, E. A. 1981. Pheromones. *In* The gypsy moth: research toward pest management. C. C. Doane and M. L. McManus, eds. U.S. Dep. Agric. For. Serv., Sci. and Educ. Agency, and Anim. and Plant Health Insp. Serv. Tech. Bull. 1584, p. 531-533.

187. Campbell, R. W. 1967. The analysis of numerical change in gypsy moth populations. For. Sci. Monogr. 15, 33 p.

188. Campbell, R. W. 1974. The gypsy moth and its natural enemies. U.S. Dep. Agric., Agric. Inf. Bull. 381, 27 p.

189. Campbell, R. W. 1981. Historical review. *In* The gypsy moth: research toward integrated pest management. C. C. Doane and M. L. McManus, eds. U.S. Dep. Agric. For. Serv., Sci. and Educ. Agency, and Anim. and Plant Health Insp. Serv. Tech. Bull. 1584, p. 65-86.

190. Campbell, R. W., and R. J. Sloan. 1977. Natural regulation of innocuous gypsy moth populations. Environ. Entomol. 6:315-322.
191. Campbell, R. W., and H. T. Valentine. 1972. Tree condition and mortality following defoliation by the gypsy moth. U.S. Dep. Agric. For. Serv., Res. Pap. NE-236, 331 p. Northeast. For. Exp. Stn., Broomall, Pa.
192. Canard, M. 1958. Recherches sur la morphologie et la biologie de la cochenille *Eulecanium corni* Bouché (Homopterès-Coccoidea). École Natl. Supér. Agron. Ann. 6(2):185-266.
193. Cannon, K. F., and W. H. Robinson. 1982. An artificial diet for the laboratory rearing of the old house borer, *Hylotrupes bajulus* (Coleoptera: Cerambycidae). Can. Entomol. 114:739-742.
194. Cantelo, W. W. 1953. Life history and control of euonymus scale in Massachusetts. Univ. Mass. Agric. Exp. Stn. Bull. 471, 31 p.
195. CANUSA [Canada/United States Spruce Budworms Program]. [1982]. Guidelines for predicting tree mortality caused by the spruce budworm, and measures for reducing losses. Can. For. Serv., Hull, Quebec. [Unpaged.]
196. Capps, H. W. 1964. Description of a new species of *Euzophora* Zeller attacking magnolias and note on two related species (Lepidoptera: Phycitidae). Fla. Entomol. 47(1):49-52.
197. Carolin, V. M., W. H. Klein, and R. M. Thompson. 1962. Eradicating European pine shoot moth on ornamental pines with methyl bromide. U.S. Dep. Agric. For. Serv., Res. Pap. 47, 16 p. Pacific Northwest For. & Range Exp. Stn., Portland, Oreg.
198. Carroll, W. J., and W. E. Waters. 1967. Eastern hemlock looper *Lambdina fiscellaria fiscellaris* (Guen.). *In* Important forest insects and diseases of mutual concern to Canada, the United States and Mexico. A. G. Davidson and R. M. Prentice, eds. Can. Dep. For. & Rural Dev. Publ. 1180, p. 120-122.
199. Carson, R. L. 1962. Silent spring. 386 p. Houghton Mifflin, Boston.
200. Castrovillo, P. J., and M. W. Stock. 1981. Electrophoretic techniques for detection of *Glypta fumiferanae*, an endoparasite of western spruce budworm. Entomol. Exp. & Appl. 30:176-180.
201. Chamberlin, W. J. 1939. The bark and timber beetles of North America north of Mexico: the taxonomy, biology and control of 575 species belonging to 72 genera of the super family *Scolytoidea*. 513 p. OSC Coop. Assoc., Corvallis, Oreg.
202. Chapman, J. W. 1910. The introduction of a European scolytid (the smaller elm bark-beetle, *Scolytus multistriatus* Marsh.) into Massachusetts. Psyche: J. Entomol. 17(2): 63-68.
203. Chellman, C. A. 1969. Record of *Acantholyda circumcincta* (Hymenoptera: Pamphiliidae) in Florida. Fla. Entomol. 52:51.
204. Chemsak, J. A., and E. G. Linsley, compilers. 1982. Checklist of Cerambycidae, the longhorned beetles: Checklist of the Cerambycidae and Disteniidae of North America, Central America, and the West Indies (Coleoptera). 138 p. Plexus Publ., Inc., Medford, N.J.
205. Christian, M. B. 1939. Experiments on the prevention of ambrosia beetle damage in hardwoods. South. Lumberman 159(2009):110-112.
206. Christian, M. B. 1940. Biology of the powder-post beetles, *Lyctus planicollis* Leconte and *Lyc-*

tus parallelopipedus (Melsh.). Part I. La. Conserv. Rev. 9(4): 56-59.

207. Christian, M. B. 1941. Biology of the powder-post beetles, *Lyctus planicollis* Leconte and *Lyctus parallelopipedus* (Melsh.). Part II. La. Conserv. Rev. 10(1):40-42.

208. Ciesla, W. M. 1964. The feeding preference for hardwoods by elm spanworm in the Southern Appalachian Mountains. J. Econ. Entomol. 57(4):604.

209. Ciesla, W. M. 1965. Observations of the life history of *Telenomus alsophilae*, an egg parasite of the elm spanworm, *Ennomos subsignarius*. J. Econ. Entomol. 58(4):702-704.

210. Ciesla, W. M. 1969. Forecasting population trends of an oak leaf tier, *Croesia semipurpurana*. J. Econ. Entomol. 62:1054-1056.

211. Ciesla, W. M., and R. E. Acciavatti. 1982. Panoramic aerial photography for mapping gypsy moth defoliation. U.S. Dep. Agric., For. Serv. MAG Rep. 83-1, 17 p. For. Pest Manage., Manage. Appl. Group, Ft. Collins, Colo.

212. Ciesla, W. M., J. C. Bell, Jr., and J. W. Curlin. 1967. Color photos and the southern pine beetle. Photogramm. Eng. 33(3):883-888.

213. Ciesla, W. M., and L. E. Drake. 1969. Evaluation of forest tent caterpillar infestations in southwestern Alabama. U.S. Dep. Agric. For. Serv. and Southeast. Area State & Priv. For., Div. For. Pest Control Rep. 69-2-50, 3 p. Pineville, La.

214. Clark, E. W. 1975. Reproductive diapause in *Hylobius pales*. Ann. Entomol. Soc. Am. 68:349-352.

215. Clarke, J. F. Gates.(J. F. Gates-Clarke.) 1941. Revision of the North American moths of the family Oecophoridae, with descriptions of new genera and species. Proc. U.S. Natl. Mus. 90(3107):33-286.

216. Clausen, C. P. 1940. Entomophagous insects. 688 p. McGraw-Hill Book Co., Inc., New York and London.

217. Clausen, C. P. 1956. Biological control of insect pests in the continental United States. U.S. Dep. Agric., Tech. Bull. 1139, 151 p.

218. Clausen, C. P., ed. 1978. Introduced parasites and predators of arthropod pests and weeds: a world review. U.S. Dep. Agric., Agric. Res. Serv., Agric. Handb. 480, 545 p.

219. Cole, M. M., P. H. Clark, and C. N. Smith. 1960. Toxicants for body lice control. Soap & Chem. Spec. 36(5): 101-104, 160-161.

220. Coleman, V. R. 1978. Dogwood borers. Univ. Ga. Coop. Ext. Serv. Leafl. 60, 2 p. Athens, Ga.

221. Collins, C. W. 1915. Dispersion of gipsy-moth larvae by the wind. U.S. Dep. Agric. Bull. 273, 23 p.

222. Collins, C. W. 1926. Observations on a recurring outbreak of *Heterocampa guttivitta* Walker and natural enemies controlling it. J. Agric. Res. 32(7): 689-699.

223. Collins, C. W. 1933. The oriental moth *(Cnidocampa flavescens* Walk.) and its control. U.S. Dep. Agric. Circ. 277, 8 p.

224. Collins, C. W., W. D. Buchanan, R. R. Whitten, and C. H. Hoffmann. 1936. Bark beetles and other possible insect vectors of the Dutch elm disease *Ceratostomella ulmi* (Schwarz) Buisman. J. Econ. Entomol. 29(1):169-176.

225. Collins, C. W., and S. F. Potts. 1932. Attractants for the flying gypsy moths as an aid in locating new infestations. U.S. Dep. Agric., Tech. Bull. 336, 4 p.

226. Collins, M. M., and R. D. Weast. 1961. Wild silk moths of

the United States; Saturniidae. 138 p. Collins Radio Co., Cedar Rapids, Iowa.

227. Commonwealth Institute of Biological Control. 1971. Biological control programmes against insects and weeds in Canada 1959-1968. Commonw. Inst. Biol. Control, Agric. Bur. Tech. Commun. 4, 266 p. [Commonw. Agric. Bur., Farnham Royal, Slough, England.]

228. Commonwealth Institute of Entomology. 1977. Distribution maps of pests. Pest: *Amphimallon majalis* (Razoum.) Col., Melolonthidae (European chafer). Host plants: turf grasses, cereals, legumes, conifers. No. 371, 2 p. 56 Queen's Gate, London.

229. Comstock, J. H. 1940. The spider book. Rev. and ed. by W. J. Gertsch. 729 p. Doubleday, Doran & Co., Inc., New York.

230. Comstock, J. H. 1947. An introduction to entomology. 9th ed., rev. 1064 p. Comstock Publ. Co., Inc., Ithaca, N.Y.

231. Condrashoff, S. F. 1964. Bionomics of the aspen leaf miner, *Phyllocnistis populiella* Cham. (Lepidoptera: Gracillariidae). Can. Entomol. 96(6):857-874.

232. Connell, W. A. 1956. Nitidulidae of Delaware. Univ. Del. Agric. Exp. Stn. Bull. 318 (Tech.), 67 p.

233. Connell, W. A., and J. H. Beacher. 1947. Life history and control of the oak lace bug. Univ. Del. Agric. Exp. Stn. Bull. 265 (Tech. 37), 28 p.

234. Connola, D. P., W. E. Waters, and E. R. Nason. 1959. A sequential sampling plan for redpine sawfly *Neodiprion nanulus* Schedl. J. Econ. Entomol. 52(4):600-602.

235. Connola, D. P., W. E. Waters, and W. E. Smith. 1957. The development and application of a sequential sampling plan for forest tent caterpillar in New York. N.Y. State Mus. & Sci. Serv. Bull. 366, 22 p.

236. Connola, D. P., and E. C. Wixson. 1963. White pine weevil attack: in relation to soils and other environmental factors in New York. N.Y. State Mus. & Sci. Serv. Bull. 389, 80 p.

237. Connor, M. D., M. W. Houseweart, and H. M. Kulman. 1982. Susceptibility of white spruce seed sources to yellowheaded spruce sawflies, *Pikonema alaskensis* (Hymenoptera: Tenthredinidae). Great Lakes Entomol. 15:207-311.

238. Coppel, H. C., and D. M. Benjamin. 1965. Bionomics of the Nearctic pine-feeding diprionids. Annu. Rev. Entomol. 10:69-96.

239. Coppel, H. C., J. E. Casida, and W. C. Dauterman. 1960. Evidence for a potent sex attractant in the introduced pine sawfly, *Diprion similis* (Hymenoptera: Diprionidae). Ann. Entomol. Soc. Am. 53(4):510-512.

240. Coppel, H. C., and J. W. Mertins. 1977. Biological insect pest suppression. 314 p. Adv. Ser. Agric. Sci. 4. Springer-Verlag, Berlin.

241. Coppel, H. C., J. W. Mertins, and J. W. E. Harris. 1974. The introduced pine sawfly, *Diprion similis* (Hartig) (Hymenoptera: Diprionidae). A review with emphasis on studies in Wisconsin. Univ. Wis., Res. Div., Res. Bull. R2393, 74 p.

242. Corneil, J. A., and L. F. Wilson. 1980. Pales weevil—rationale for its injury and control. Mich. Christmas Tree J. 1980 (Fall):16-17.

243. Cornell, J. F. 1972. Larvae of families of Coleoptera: a bibliographic survey of recent papers and tabular summary of 7 selected English language contributions. Coleopt. Bull. 26(3):81-96.

244. Corrette, K. B., and H. H. Neun-

zig. 1979. Descriptions of and notes on larval habits of four immature phycitines in the southeastern United States (Lepidoptera: Pyralidae). Ann. Entomol. Soc. Am. 72:690-699.

245. Coster, J. E. 1969. Observations on *Platypus flavicornis* (Coleoptera: Platypodidae) in southern pine beetle infestations. Ann. Entomol. Soc. Am. 62:1008-1011.

246. Coster, J. E., and J. L. Searcy, eds. 1979. Evaluating control tactics for southern pine beetle: symposium proceedings. [Many, La., January 1979.] U.S. Dep. Agric., Comb. For. Pest Res. & Dev. Program, Tech. Bull. 1613, 118 p.

247. Coster, J. E., and J. L. Searcy, eds. 1981. Site, stand, and host characteristics of southern pine beetle infestations. U.S. Dep. Agric., Comb. For. Pest Res. & Dev. Program, Tech. Bull. 1612, 115 p.

248. Cote, W. A., III, and D. C. Allen. 1973. Biology of the maple trumpet skeletonizer, *Epinotia acriella* (Lepidoptera: Olethreutidae), in New York. Can. Entomol. 105(3): 463-470.

249. Cote, W. A., III, and D. C. Allen. 1980. Biology of two-lined chestnut borer, *Agrilus bilineatus*, in Pennsylvania and New York. Ann. Entomol. Soc. Am. 73:409-413.

250. Cotter, H. V. T., and R. O. Blanchard. 1981. Identification of two *Nectria* causing bole cankers on American beech. Plant Dis. 65:332-334.

251. Couch, J. N. 1931. The biological relationship between *Septobasidium retiforme* (B. & C.) Pat. and *Aspidiotus osborni* New. and Ckll. Q. J. Microsc. Sci. (n.s.) 74(295):383-437.

252. Coulson, J. R. 1981. Recent history: 1961-1977. *In* The gypsy moth: research toward integrated pest management. C. C. Doane and M. L. McManus, eds. U.S. Dep. Agric. For. Serv., Sci. and Educ. Agency, and Anim. and Plant Health Insp. Serv. Tech. Bull. 1584, p. 302-310.

253. Coulson, R. N., T. L. Payne, J. E. Coster, and M. W. Houseweart. 1972. The southern pine beetle *Dendroctonus frontalis* Zimm. (Coleoptera: Scolytidae). Tex. For. Serv. Publ. 108, 38 p.

254. Courtemanch, D. L., and K. E. Gibbs. 1980. Short- and long-term effects of forest spraying of carbaryl (Sevin-4-011®) on stream invertebrates. Can. Entomol. 112:271-276.

255. Coyne, J. F. 1968. *Laspeyresia ingens*, a seedworm infesting cones of longleaf pine. Ann. Entomol. Soc. Am. 61(5): 1116-1122.

256. Coyne, J. F. 1968. *Neodiprion taedae linearis:* a sawfly pest of loblolly and shortleaf pines. U.S. Dep. Agric. For. Serv., For. Pest Leafl. 34 rev., 4 p.

257. Craighead, F. C. 1915. Contributions toward a classification and biology of the North American Cerambycidae. Larvae of the Prioninae. U.S. Dep. Agric. Off. of the Secr. Rep. 107, 24 p.

258. Craighead, F. C. 1921. Protection of mesquite cordwood and posts from borers. U.S. Dep. Agric., Farmers' Bull. 1197, 12 p.

259. Craighead, F. C. 1923. North American cerambycid larvae. A classification and the biology of North American cerambycid larvae. Can. Dep. Agric., Entomol. Branch Bull. 27, 239 p.

260. Craighead, F. C. 1928. Interrelation of tree-killing barkbeetles *(Dendroctonus)* and blue stains. J. For. 26(7):886-887.

261. Craighead, F. C. 1950. Insect enemies of eastern forests. U.S. Dep. Agric., Misc. Publ. 657, 679 p.

262. Craighead, F. C., and J. M. Miller. 1949. Insects in the forest: a

survey. *In* Trees. U.S. Dep. Agric., Yearb. Agric. 1949, p. 407-413.

263. Crandall, B. S., and W. L. Baker. 1950. The wilt disease of American persimmon, caused by *Cephalosporium diospyri*. Phytopathology 40(4):307-325.
264. Creighton, J. T. 1937. *Homaledra sabalella* Chambers, the major pest of palms in Florida. J. Econ. Entomol. 30(4):590-595.
265. Creighton, W. S. 1950. The ants of North America. Harv. Coll. Bull. Mus. Comp. Zool. 104, 585 p.
266. Cressman, A. W., and H. K. Plank. 1935. The camphor scale. U.S. Dep. Agric. Circ. 365, 20 p.
267. Crossman, S. S. 1925. Two imported egg parasites of the gipsy moth, *Anastatus bifasciatus* Fonsc. and *Schedius kuvanae* Howard. J. Agric. Res. 30(7): 643-675.
268. Crumb, S. E. 1956. The larvae of the Phalaenidae. U.S. Dep. Agric., Tech. Bull. 1135, 356 p.
269. Culver, J. J. 1919. A study of *Compsilura concinnata*, an imported tachinid parasite of the gipsy moth and the brown-tail moth. U.S. Dep. Agric. Bull. 766, 27 p.
270. Cuming, F. G. 1961. The distribution, life history, and economic importance of the winter moth, *Operophtera brumata* (L.) (Lepidoptera, Geometridae) in Nova Scotia. Can. Entomol. 93(2):135-142.
271. Cumming, M. E. P. 1959. The biology of *Adelges cooleyi* (Gill.) (Homoptera: Phylloxeridae). Can. Entomol. 91(10):601-617.
272. Cumming, M. E. P. 1968. The life history and morphology of *Adelges lariciatus* (Homoptera: Phylloxeridae). Can. Entomol. 100(2):113-126.
273. Curran, C. H. 1934. The families and genera of North American Diptera. 512 p. Ballou Press, New York.
274. Cuthbert, R. A., W. N. Cannon, Jr., and J. W. Peacock. 1975. Relative importance of root grafts and bark beetles to the spread of Dutch elm disease. U.S. Dep. Agric. For. Serv., Res. Note NE-206, 4 p. Northeast. For. Exp. Stn., Broomall, Pa.
275. Cymorek, S. 1971. Über notwendige Temperatur-Zeit-Verhaltnisse zum Abotöten von Lyctus-Larven bezogen auf die Heissverleimung von Türen. Deutsche Gesellschaft für Holzforschung. [Temperature/time conditions required to kill *Lyctus* larvae, in connexion with the hot gluing of doors.] Mitt. Dtsch. Ges. Holzforsch. 57:50-57. (Abstr.) For. Abstr. 33(4): 819.
276. Darling, D. C., and N. F. Johnson. 1982. Egg mortality in the eastern tent caterpillar, *Malacosoma americanum* (Lepidoptera: Lasiocampidae): the role of the accessory gland secretions and egg mass shape. Proc. Entomol. Soc. Wash. 84:448-460.
277. Daviault, L. 1956. The red pine web-spinning sawfly, *Cephalcia marginata* Middlekauff (Hymenoptera, Pamphiliidae). Can. Entomol. 88(8):488-492.
278. Daviault, L., and R. Ducharme. 1966. Life history and habits of the green spruce leaf miner, *Epinotia nanana* (Treitschke) (Lepidoptera: Tortricidae). Can. Entomol. 98(7): 693-699.
279. Davidson, J. A., and C. W. McComb. 1958. Notes on the biology and control of *Fiorinia externa* Ferris. J. Econ. Entomol. 51(3):405-406.
280. Davidson, J. A., D. R. Miller, and S. Nakahara. 1983. The white peach scale, *Pseudaulacaspis pentagona* (Targioni-Tozzetti): evidence that current

concepts include two species. Proc. Entomol. Soc. Wash. 85(4):753-761.

281. Davidson, R. H., and B. J. Landis. 1938. *Crabro davidsoni* Sandh., a wasp predacious on adult leafhoppers. Ann. Entomol. Soc. Am. 31(1):5-8.

282. Davis, D. R. 1964. Bagworm moths of the Western Hemisphere (Lepidoptera: Psychidae). U.S. Natl. Mus. Bull. 244, 233 p.

283. Dean, G. A. 1946. The elm calligrapha *(Calligrapha scalaris* LeC.). Kans. State Coll. Agric. Exp. Stn., Agric. & Appl. Sci. Circ. 234, 7 p.

284. DeBach, P., ed. 1964. Biological control of insect pests and weeds. 877 p. Reinhold Publ. Corp., New York.

285. DeBach, P., and T. W. Fisher. 1956. Experimental evidence for sibling species in the oleander scale, *Aspidiotus hederae* (Vallot). Ann. Entomol. Soc. Am. 49(3):235-239.

286. DeBarr, G. L. 1967. Two new sucking insect pests of seed in southern pine seed orchards. U.S. Dep. Agric. For. Serv., Res. Note SE-78, 3 p. Southeast. For. Exp. Stn., Asheville, N.C.

287. DeBarr, G. L. 1970. Characteristics and radiographic detection of seedbug damage to slash pine seed. Fla. Entomol. 53:109-117.

288. DeBarr, G. L., L. R. Barber, C. W. Berisford, and J. C. Weatherby. 1982. Pheromone traps detect webbing coneworms in loblolly pine seed orchards. South. J. Appl. For. 6:122-127.

289. DeBarr, G. L., and B. H. Ebel. 1974. Conelet abortion and seed damage of shortleaf and loblolly pines by a seedbug, *Leptoglossus corculus*. For. Sci. 20:165-170.

290. DeBarr, G. L., and E. R. Merkel. 1971. Mist blower spraying of longleaf pine for cone and seed insect control. U.S. Dep. Agric. For. Serv., Res. Pap. SE-76, 7 p. Southeast. For. Exp. Stn., Asheville, N.C.

291. DeBoo, R. F., W. L. Sippell, and H. R. Wong. 1971. The eastern pine-shoot borer, *Eucosma gloriola* (Lepidoptera: Tortricidae), in North America. Can. Entomol. 103(10): 1473-1486.

292. de Groot, P., J. C. Cunningham, and J. R. McPhee. 1979. Control of red-headed pine sawfly with a baculovirus in Ontario in 1978 and a survey of areas treated in previous years. Dep. Environ., Can. For. Serv., For. Pest Manage. Inst. Rep. FPM-X-20, 14 p. Sault Ste. Marie, Ont.

293. Dekle, G. W. 1963. Puteanum scale *(Asterolecanium puteanum* Russell). Fla. Dep. Agric., Div. Plant Ind. Circ. 13, 2 p.

294. Dekle, G. W. 1965. Florida armored scale insects. *In* Arthropods of Florida and neighboring land areas, vol. 3. 265 p. Fla. Dep. Agric., Div. Plant Ind., Gainesville, Fla.

295. DeLong, D. M. 1948. The leafhoppers, or Cicadellidae, of Illinois (Eurymelinae-Balcluthinae). Bull. Ill. Nat. Hist. Surv. 24 (Artic. 2), 376 p.

296. DeMars, C. J., G. W. Slaughter, L. E. Greene, and J. H. Ghent. 1982. Mapping pine mortality by aerial photography, Umstead Park, North Carolina. U.S. Dep. Agric. For. Serv., Res. Pap. PSW-158, 14 p. Pacific Southwest For. & Range Exp. Stn., Berkeley, Calif.

297. Denmark, H. A. 1960. Some observations on the biology of *Anchylopera platanana* Clemens (Lepidoptera, Olethreutidae) in Florida. Fla. Entomol. 43(2):81-87.

298. Denton, R. E. 1958. The larch casebearer in Idaho—a new de-

foliator record for western forests. U.S. Dep. Agric. For. Serv., Res. Note 51, 6 p. Intermt. For. & Range Exp. Stn., Ogden, Utah.

299. Denton, R. E. 1972. Establishment of *Agathis pumila* (Ratz.) for control of larch casebearer, and notes on native parasitism and predation in Idaho. U.S. Dep. Agric. For. Serv., Res. Note INT-164, 6 p. Intermt. For. & Range Exp. Stn., Ogden, Utah.

300. Department of Scientific and Industrial Research. 1956. A handbook of hardwoods. 269 p. For. Prod. Res., H. M. Stationery Off., London.

301. DeSwarte, D. H., and E. U. Balsbaugh, Jr. 1973. Biologies of *Altica subplicata* and *Disonycha alternata* (Coleoptera: Chrysomelidae), two flea beetles that feed on the sandbar willow. Ann. Entomol. Soc. Am. 66:1349-1353.

302. Dethier, V. G. 1980. The world of the tent-makers. A natural history of the eastern tent caterpillar. 148 p. Univ. Mass. Press, Amherst, Mass.

303. Dietrich, H. 1945. The Elateridae of New York State. Cornell Univ. Agric. Exp. Stn. Mem. 269, 79 p.

304. Dillon, E. S., and L. S. Dillon. 1961. A manual of common beetles of eastern North America. 884 p. Row, Peterson & Co., Evanston, Ill.

305. Dillon, L. S. 1956. The nearctic components of the tribe Acanthocinini (Coleoptera: Cerambycidae). Ann. Entomol. Soc. Am., Part II, 49(3): 207-235.

306. Dindal, D. L., and L. J. Metz. 1977. Community structure of Collembola affected by fire frequency. *In* Proc. in Life Sciences. The role of Arthopods in forest ecosystems. p. 88-95. W. F. Mattson, ed. Springer-Verlag, New York.

307. Dix, M. E., and D. T. Jennings. 1982. *Rhyacionia bushnelli* (Lepidoptera: Tortricidae) damaged tips within ponderosa pine: distribution and sampling universe. Can. Entomol. 114:403-409.

308. Dixon, W. E., and M. Houseweart. 1982. Life tables of the white pine weevil, *Pissodes strobi*, in central Maine. Environ. Entomol. 11:555-564.

309. Dixon, W. E., M. W. Houseweart, and S. M. Sheffer. 1979. Fall temporal activity and overwintering sites of the white pine weevil, *Pissodes strobi*, in central Maine. Ann. Entomol. Soc. Am. 72:840-844.

310. Dixon, J. C., and E. A. Osgood. 1961. Southern pine beetle: a review of present knowledge. U.S. Dep. Agric. For. Serv., Stn. Pap. 128, 34 p. Southeast. For. Exp. Stn., Asheville, N.C.

311. Doane, C. C. 1959. *Beauveria bassiana* as a pathogen of *Scolytus multistriatus*. Ann. Entomol. Soc. Am. 52(1): 109-111.

312. Doane, C. C. 1976. Ecology of pathogens of the gypsy moth. *In* Perspectives in forest entomology. p. 285-293. J. F. Anderson and H. K. Kaya, eds. Academic Press, New York.

313. Doane, C. C., and M. L. McManus, eds. 1981. The gypsy moth: research toward integrated pest management. U.S. Dep. Agric. For. Serv., Sci. and Educ. Agency, and Anim. and Plant Health Insp. Serv. Tech. Bull. 1584, 757 p.

314. Doane, R. W., E. C. Van Dyke, W. J. Chamberlin, and H. E. Burke. 1936. Forest insects: a textbook for the use of students in forest schools, colleges, and universities, and for forest workers. 463 p. McGraw-Hill Book Co., Inc., New York.

315. Doerksen, G. P., and H. H. Neunzig. 1975. Descriptions of some immature *Nephopterix* in

the Eastern United States (Lepidoptera: Pyralidae: Phycitinae). Ann. Entomol. Soc. Am. 68(4):623-644.

316. Doerksen, G. P., and H. H. Neunzig. 1976. Biology of some immature *Nephopterix* in the Eastern United States (Lepidoptera: Pyralidae: Phycitinae). Ann. Entomol. Soc. Am. 69(3):423- 431.

317. Doggett, C. A., C. R. Grady, C. R. Green, and others. 1977. Seedling debarking weevils in North Carolina. N.C. For. Serv., Dep. Nat. and Econ. Resour., For. Note 31, 15 p. Raleigh, N.C.

318. Dominick, R. B., D. C. Ferguson, R. W. Hodges, and others (eds.). 1971 continuing. The moths of America north of Mexico [including Greenland]. [In separate fascicles.] E. W. Classey, Ltd., R. B. D. Publ. Inc., and The Wedge Entomol. Res. Found., London.

319. Donley, D. E. 1964. Mimosa webworm and its control on individual honeylocusts with systemic insecticides. Arborist's News 29(3):17-20.

320. Donley, D. E. 1964. Season-long webworm control for honey locust. Am. Nurseryman 119(11):7-8.

321. Donley, D. E., and R. E. Acciavatti. 1980. Red oak borer. U.S. Dep. Agric., For. Insect & Dis. Leafl. 163, 7 p.

322. Donley, D. E., C. J. Hay, and J. R. Galford. 1974. Woodborer impact in Ohio oak. Ohio Woodlands 12:4-5,14.

323. Dorsey, C. K., and J. G. Leach. 1956. The bionomics of certain insects associated with oak wilt with particular reference to the Nitidulidae. J. Econ. Entomol. 49(2): 219-230.

324. Dottavio, C. L., and D. L. Williams. 1983. Satellite technology: an improved means for monitoring forest insect defoliation. J. For. 81:30-34.

325. Dowden, P. B. 1935. *Brachymeria intermedia* (Nees), a primary parasite, and *B. compsilurae* (Cwfd.), a secondary parasite of the gypsy moth. J. Agric. Res. 50(6):495-523.

326. Dowden, P. B. 1939. *Schizonotus sieboldi*, an important parasite of the imported willow leaf beetle *(Plagiodera versicolora)*. J. Agric. Res. 58(8):581- 592.

327. Dowden, P. B. 1941. Parasites of the birch leaf-mining sawfly *(Phyllotoma nemorata)*. U.S. Dep. Agric., Tech. Bull. 757, 56 p.

328. Dowden, P. B. 1962. Parasites and predators of forest insects liberated in the United States through 1960. U.S. Dep. Agric., Agric. Handb. 226, 70 p.

329. Dowden, P. B., W. D. Buchanan, and V. M. Carolin. 1948. Natural-control factors affecting the spruce budworm. J. Econ. Entomol. 41(3):457-464.

330. Dowden, P. B., V. M. Carolin, and C. O. Dirks. 1950. Natural control factors affecting the spruce budworm in the Adirondacks during 1946-1948. J. Econ. Entomol. 43(6):774-783.

331. Drooz, A. T. 1953. The wharf borer problem in Milwaukee, Wisconsin. Proc. Eighth Annu. Meet. North Cent. States Branch Am. Entomol. Soc., p. 22-23. St. Louis, Mo.

332. Drooz, A. T. 1960. The larch sawfly: its biology and control. U.S. Dep. Agric. For. Serv., Tech. Bull. 1212, 52 p.

333. Drooz, A. T. 1960. White-pine shoot borer *(Eucosma gloriola* Heinrich). J. Econ. Entomol. 53(2):248-251.

334. Drooz, A. T. 1966. Color studies of reared elm spanworm larvae and pupae. Ann. Entomol. Soc. Am. 59(3):568-573.

335. Drooz, A. T. 1967. The larch

sawfly. U.S. Dep. Agric. For. Serv., For. Pest Leafl. 8 rev., 4 p.

336. Drooz, A. T. 1975. Current research with *Telenomus alsophilae* Viereck, an egg parasite of the fall cankerworm, *Alsophila pometaria* (Harris) (Lepidoptera: Geometridae). J. N.Y. Entomol. Soc. 83(4): 283-285.

337. Drooz, A. T. 1980. A review of the biology of the elm spanworm (Lepidoptera: Geometridae). Great Lakes Entomol. 13:49-53.

338. Drooz, A. T., W. Carothers, and J. H. Ghent. 1981. *Anacacamptodes pergracilis* (Hulst), a hardly known defoliator of baldcypress. J. Elisha Mitchell Sci. Soc. 97(3): 218.

339. Drooz, A. T., C. A. Doggett, and H. C. Coppel. 1979. The introduced pine sawfly, a defoliator of white pine new to North Carolina. U.S. Dep. Agric., For. Serv. Res. Note SE-273, 3 p. Southeast. For. Exp. Stn., Asheville, N.C.

340. Drooz, A. T., and J. D. Solomon. 1964. Effects of solarization on elm spanworm eggs (Lepidoptera: Geometridae). Ann. Entomol. Soc. Am. 57:95-98.

341. Drooz, A. T., L. C. Thompson, and H. M. Kulman. 1977. Release of *Olesicampe benefactor* against the larch sawfly in Eastern United States. (Abstr.) J. Elisha Mitchell Sci. Soc. 93(2):89.

342. Drooz, A. T., R. C. Wilkinson, and V. H. Fedde. 1977. Larval and cocoon parasites of three *Neodiprion* sawflies in Florida. Environ. Entomol. 6:60-62.

343. Dubois, N. R. 1981. *Bacillus thuringiensis*. *In* The gypsy moth: research toward integrated pest management. C. C. Doane and M. L. McManus, eds. U.S. Dep. Agric. For. Serv., Sci. and Educ. Agency, and Anim. and Plant Health Insp. Serv. Tech. Bull 1584, p. 445-453.

344. Dubois, N. R., and F. B. Lewis. 1981. What is *Bacillus thuringiensis*. J. Arboric. 7:233-240.

345. Duckworth, W. D., and T. D. Eichlin. 1977. A classification of the Sesiidae of America north of Mexico (Lepidoptera:Sesioidae). 54 p. Calif. Dep. Food and Agric., Sacramento.

346. Dull, C. W. 1980. Loran-C radio navigation systems as an aid to southern pine beetle surveys. U.S. Dep. Agric., Agric. Handb. 567, 15 p.

347. Dulmage, H. T., and C. C. Beegle. 1982. *Bacillus thuringiensis* cultures available from the U.S. Department of Agriculture. U.S. Dep. Agric., Agric. Res. Serv., South Reg. ARM-S-30, 42 p. Atlanta, Ga.

348. Dunbar, D. M., and G. R. Stephens. 1975. Association of twolined chestnut borer and shoestring fungus with mortality of defoliated oak in Connecticut. For. Sci. 21:169-174.

349. Duncan, D. P., and A. C. Hodson. 1958. Influence of the forest tent caterpillar upon the aspen forests of Minnesota. For. Sci. 4(1):71-93.

350. Dutky, S. R. 1940. Two new spore-forming bacteria causing milky diseases of Japanese beetle larvae. J. Agric. Res. 61(1):57-68.

351. Dwinell, L. D., E. G. Kuhlman, and G. M. Blakeslee. 1981. Pitch canker of southern pines. *In* Fusarium: diseases, biology, and taxonomy. p. 188-194. P. E. Nelson, T. A. Toussoun and R. J. Cook, eds. Pa. State Univ. Press, University Park.

352. Dyar, H. G. 1902. A list of North American Lepidoptera and key to the literature of this order of insects. U.S. Natl. Mus. Bull. 52, 723 p.

353. Eastop, V. F., and D. H. R. Lambers. 1976. Survey of the world's aphids. 573 p. Dr. W. Junk b.v., Publishers. The Hague, Netherlands.
354. Eaton, C. B., J. A. Beal, R. L. Furniss, and C. F. Speers. 1949. Airplane and helicopter spraying with DDT for spruce budworm control. J. For. 47(10):823-827.
355. Eaton, C. B., and J. S. Yuill. 1960. Gouty pitch midge. U.S. Dep. Agric. For. Serv., For. Pest Leafl. 46, 8 p.
356. Ebel, B. H. 1961. Thrips injure slash pine female flowers. J. For. 59(5):374-375.
357. Ebel, B. H. 1965. The *Dioryctria* coneworms of north Florida pines (Lepidoptera: Phycitidae). Ann. Entomol. Soc. Am. 58(5):623-630.
358. Ebel, B. H. 1966. Rearing and occurrence of xyelid sawflies on slash and longleaf pines in north Florida (Hymenoptera: Xyelidae). Ann. Entomol. Soc. Am. 59(1):227-229.
359. Ebel, B. H., and G. L. DeBarr. 1973. Injury to female strobili of shortleaf and loblolly pines by *Nepytia semiclusaria* (Lepidoptera: Geometridae). Fla. Entomol. 56: 53-55.
360. Ebel, B. H., T. H. Flavell, L. E. Drake, H. O. Yates III, and G. L. DeBarr. 1980. Seed and cone insects of southern pines. U.S. Dep. Agric. For. Serv., Gen. Tech. Rep. SE-8, rev., 43 p. Southeast. For. Exp. Stn., Asheville, N.C., and Southeast. Area, State & Priv. For., Atlanta, Ga.
361. Ebel, B. H., and E. P. Merkel. 1967. *Hylobius* weevil larvae attack roots of young slash pines. For. Sci. 13(1):97-99.
362. Ebel, B. H., and H. O. Yates III. 1974. Insect-caused damage and mortality to conelets, cones and seed of shortleaf pine. J. Econ. Entomol. 67(2):222-226.
363. Ebeling, W. 1938. Host-determined morphological variations in *Lecanium corni*. Hilgardia 11(11):613-631.
364. Ebeling, W. 1959. Subtropical fruit pests. 436 p. Univ. Calif., Div. Agric. Sci., Los Angeles.
365. Ebeling, W. 1968. Termites: identification, biology, and control of termites attacking buildings. Univ. Calif., Calif. Agric. Exp. Stn., Ext. Serv. Man. 38, 74 p.
366. Ebeling, W. 1975. Urban entomology. 695 p. Univ. Calif., Div. Agric. Sci., Los Angeles.
367. Ebeling, W., and D. A. Reierson. 1973. Leadcable borers infesting houses. Natl. Pest Control Oper. News 33(8):16-17.
368. Echols, H. W. 1963. The biology, distribution, and insecticidal control of pine colaspis (*Colaspis pini* Barber) in Louisiana. M.S. Thesis, La. State Univ., Baton Rouge.
369. Echols, H. W. 1966. Texas leafcutting ant controlled with pelleted Mirex bait. J. Econ. Entomol. 59(3):628-631.
370. Eddy, G. W., and R. C. Bushland. 1946. Control of human lice. U.S. Dep. Agric., Bur. Entomol. & Plant Quar., E-685, 5 p.
371. Edmunds, G. F., Jr. 1973. Ecology of black pineleaf scale (Homoptera: Diaspididae). Environ. Entomol. 2(5):765-777.
372. Edmunds, G. F., Jr., and D. N. Alstad. 1978. Coevolution in insect herbivores and conifers. Science 199:941-945.
373. Edwards, J. G. 1949. Coleoptera or beetles east of the Great Plains. 181 p. Edwards Bros. Inc., Ann Arbor, Mich.
374. Edwards, W. H. 1879-97. The butterflies of North America. 3 vols. Houghton, Boston.
375. Eidt, D. C. 1965. The life history of a web-spinning sawfly of spruce, *Cephalcia fascipennis* (Cresson) (Hymenoptera: Pamphiliidae). Can. Entomol. 97(2): 148-153.

376. Eidt, D. C., and J. O. Nichols. 1970. An outbreak of a sawfly, *Pamphilius phyllisae* (Hymenoptera: Pamphiliidae), on northern red oak, with notes on larval morphology. Can. Entomol. 102:53-63.

377. Eisner, T., A. F. Kluge, J. C. Carrel, and J. Meinwold. 1972. Defense mechanisms of arthropods. XXXIV. Formic acid and acyclic ketones in the spray of a caterpillar. Ann. Entomol. Soc. Am. 65:765-766.

378. Ellenberger, J. S., and E. A. Cameron. 1977. The spatial distribution of oak leafroller egg masses on primary host trees. Environ. Entomol. 6(1): 101-106.

379. El-Minshawy, A. M., S. K. El-Sawaf, S. M. Hammad, and A. Donia. 1971. Biology of *Hemiberlesia lataniae* (Sig.) in Alexandria District. Hemiptera-Homoptera-Diaspididae. Bull, Soc. Entomol. d'Egypte 55:441- 446.

380. Ely, C. R. 1917. A revision of the North American Gracillariidae from the standpoint of venation. Proc. Entomol. Soc. Wash. 19(1-4):29-77.

381. Embree, D. G. 1958. The external morphology of the immature stages of the beech leaf tier, *Psilocorsis faginella* (Chamb.) (Lepidoptera: Oecophoridae), with notes on its biology in Nova Scotia. Can. Entomol. 90(3):166-174.

382. Embree, D. G. 1965. The population dynamics of the winter moth in Nova Scotia, 1954-62. Mem. Entomol. Soc. Can. 46, 57 p.

383. Embree, D. G. 1966. The role of introduced parasites in the control of the winter moth in Nova Scotia. Can. Entomol. 98(11):1159-1168.

384. Engelhardt, G. P. 1946. The North American clear-wing moths of the family Aergeriidae. U.S. Natl. Mus. Bull. 190, 222 p.

385. Erickson, E. H., W. R. Enns, and F. G. Werner. 1976. Bionomics of the bee associated Meloidae (Coleoptera); bee and plant hosts of some Nearctic Meloid beetles—a synopsis. Ann. Entomol. Soc. Am. 69(5):959-970.

386. Essig, E. O. 1942. College entomology. 900 p. Macmillan Co., New York.

387. Ewan, H. G. 1957. Jack-pine sawfly. U.S. Dep. Agric. For. Serv., For. Pest Leafl. 17, 4 p.

388. Ewan, H. G. 1960. The poplar borer in relation to aspen stocking. U.S. Dep. Agric. For. Serv., Lake States For. Exp. Stn., Tech. Notes 580, 2 p. [North Central For. Exp. Stn., St. Paul, Minn.]

389. Ewan, H. G. 1961. The Saratoga spittlebug: a destructive pest in red pine plantations. U.S. Dep. Agric., Tech. Bull. 1250, 52 p.

390. Ewing, H. E. 1929. A manual of external parasites. 225 p. C. C. Thomas (publ.), Springfield, Ill.

391. Farris, M. E., and J. E. Appleby. 1979. The walnut caterpillar, *Datana integerrima* G. & R. *In* Walnut insects and diseases. U.S. Dep. Agric., For. Serv. Gen. Tech. Rep. NC-52, p. 22-28. North Central For. Exp. Stn., St. Paul, Minn.

392. Farris, S. H. 1963. Ambrosia fungus storage in two species of *Gnathotrichus* Eichhoff (Coleoptera: Scolytidae). Can. Entomol. 95:257-259.

393. Farris, S. H. 1969. Occurrence of mycangia in the bark beetle *Dryocoetes confusus* (Coleoptera: Scolytidae). Can. Entomol. 101:527-532.

394. Fattig, P. W. 1947. The Cerambycidae or long-horned beetles of Georgia. Emory Univ. Mus. Bull. 5, 48 p.

395. Fedde, G. F. 1971. Elm spanworm. U.S. Dep. Agric. For. Serv., For. Pest Leafl. 81 rev., 6 p.
396. Fedde. G. F. 1972. Status of imported and native predators of the balsam woolly aphid on Mt. Mitchell. North Carolina. U.S. Dep. Agric. For. Serv., Res. Note SE-175, 4 p. Southeast. For. Exp. Stn., Asheville, N.C.
397. Fedde. G. F. 1977. The fall cankerworm, a biological maverick. North. Nut Grow. Assoc. Annu. Rep. 68:76-84.
398. Fedde, G. F. 1977. A laboratory study of egg parasitism capabilities of *Telenomus alsophilae*. Environ. Entomol. 6:773-776.
399. Fedde, V. H. 1977. Catching up with the fall cankerworm. North. Nut Grow. Assoc. Annu. Rep. 68:69-76.
400. Felt, E. P. 1925. Key to gall midges: (A résumé of studies I-VII, Honididae). N.Y. State Mus. Bull. 257, 239 p.
401. Felt. E. P., and L. H. Joutel. 1904. Monograph of the genus Saperda. N.Y. State Mus. Bull. 74, 86 p.
402. Fenton. F. A. 1942. The flatheaded apple tree borer (*Chrysobothris femorata* (Olivier)). Okla. Agric. Exp. Stn., Bull. B-259, 31 p.
403. Ferguson, D. C. 1971-1972. Bombycoidea (Saturniidae). *In* The moths of America north of Mexico, Fasc. 20.2. p. 1-275. R. B. Dominick. and others. eds. E. W. Classey, Ltd. and R. B. D. Publ., Inc., & The Wedge Entomol. Res. Found., London.
404. Ferguson, D. C. 1978. Noctuoidea, Lymantriidae. *In* The moths of America north of Mexico, Fasc. 22.2 p. 1-100. R. B. Dominick. and others. eds. E. W. Classey Ltd., R. B. D. Publ., Inc., & The Wedge Entomol. Res. Found., London.
405. Ferris. G. F. 1937. Atlas of the scale insects of North America. Ser. 1, Nos. 1-136. Stanford Univ. Press, Calif.
406. Ferris, G. F. 1938. Atlas of the scale insects of North America. Ser. 2, Nos. 137- 268. Stanford Univ. Press, Calif.
407. Ferris, G. F. 1941. Atlas of the scale insects of North America. Ser. 3, Nos. 269- 384. Stanford Univ. Press, Calif.
408. Ferris, G. F. 1942. Atlas of the scale insects of North America. Ser. 4, Nos. 385- 448. Stanford Univ. Press, Calif.
409. Ferris, G. F. 1950. Atlas of the scale insects of North America. The Pseudococcidae (Part I). vol. V, p. 1-278. Stanford Univ. Press, Calif.
410. Ferris, G. F. 1951. The sucking lice. Mem. Pac. Coast Entomol. Soc. 1:1-320.
411. Ferris, G. F. 1953. Atlas of the scale insects of North America. The Pseudococcidae (Part II). vol. VI, p. 279-506. Stanford Univ. Press, Calif.
412. Ferris, G. F. 1955. Atlas of the scale insects of North America. The families Aclerdidae, Asterolecaniidae, Conchaspididae, Dactylopiidae, and Lacciferidae. vol. VII, p. 1-233. Stanford Univ. Press, Calif.
413. Field, W. D., C. F. Dos Passos, and J. H. Masters. 1974. A bibliography of the catalogs, lists, faunal and other papers on the butterflies of North America north of Mexico arranged by state and province (Lepidoptera: Rhopalocera). Smithson. Contrib. Zool. 157, 104 p.
414. Finnegan, R. J. 1958. The pine weevil, *Pissodes approximatus* Hopk., in southern Ontario. Can. Entomol. 90(6):348-354.
415. Finnegan, R. J. 1959. The pales weevil, *Hylobius pales* (Hbst.), in southern Ontario. Can. Entomol. 91(10):664-670.
416. Finnegan, R. J. 1961. A field key to the North American spe-

cies of *Hylobius* (Curculionidae). Can. Entomol. 93:501-502.

417. Finnegan, R. J. 1962. The pine root-collar weevil, *Hylobius radicis* Buch., in southern Ontario. Can. Entomol. 94(1):11-17.

418. Finnegan, R. J. 1965. The pine needle miner, *Exoteleia pinifoliella* (Chamb.) (Lepidoptera: Gelechiidae) in Quebec. Can. Entomol. 97(7):744-750.

419. Finnegan, R. J. 1967. Notes on the biology of the pitted ambrosia beetle, *Corthylus punctatissimus* (Coleoptera: Scolytidae), in Ontario and Quebec. Can. Entomol. 99(1):49-54.

420. Finnegan, R. J., and P. A. Godwin. 1967. Northern pine weevil: *Pissodes approximatus* Hopk. *In* Important forest insects and diseases of mutual concern to Canada, the United States and Mexico. A. G. Davidson and R. M. Prentice, eds. Can. Dep. For. & Rural Dev. Publ. 1180, p. 145-147.

421. Fisher, R. C., G. H. Thompson, and W. E. Webb 1953. Ambrosia beetles in forest and sawmill, their biology, economic importance, and control. Part I: Biology and economic importance. For. Abstr. 14(4):381-389.

422. Fisher, R. C., G. H. Thompson, and W. E. Webb. 1954. Ambrosia beetles in forest and sawmill, their biology, economic importance, and control. Part II. Prevention and control. For. Abstr. 15(1):3-15.

423. Fisher, W. S. 1928. A revision of the North American species of buprestid beetles belonging to the genus *Agrilus*. Smithson. Inst., U.S. Natl. Mus. Bull. 145, 347 p.

424. Fisher, W. S. 1942. A revision of the North American species of buprestid beetles belonging to the tribe Chrysobothrini. U.S. Dep. Agric., Misc. Publ. 470, 271 p.

425. Fisher, W. S. 1950. A revision of the North American species of beetles belonging to the family Bostrichidae. U.S. Dep. Agric., Misc. Publ. 698, 157 p.

426. Flanders, S. E. 1970. Observations on host plant induced behavior of scale insects and their endoparasites. Can. Entomol. 102(8):913-926.

427. Fleming, W. E. 1972. The Japanese beetle in the United States. U.S. Dep. Agric., Tech. Bull. 1449, 129 p.

428. Florence, L. Z., and D. L. Kulhavy. 1981. Genetic variation and population structure of the southern pine beetle, *Dendroctonus frontalis*. *In* Application of genetics and cytology in insect systematics and evaluation. p. 141-152. M. W. Stock, ed. For. Wildl. and Range Exp. Stn., Univ. Idaho, Moscow.

429. Folsom, J. W. 1937. Nearctic Collembola or springtails, of the family Isotomidae. Smithson. Inst., U.S. Natl. Mus. Bull. 168, 144 p.

430. Foote, R. H. 1965. Family Cecidomyiidae (Itonididae). *In* A catalog of the Diptera of America north of Mexico. U.S. Dep. Agric., Agric. Handb. 276, p. 241-295.

431. Foote, R. H., and D. R. Cook. 1959. Mosquitoes of medical importance. U.S. Dep. Agric., Agric. Handb. 152, 158 p.

432. Forbes, R. S., and L. Daviault. 1964. The biology of the mountain-ash sawfly, *Pristiphora geniculata* (Htg.) (Hymenoptera: Tenthredinidae), in eastern Canada. Can. Entomol. 96(8):1117-1133.

433. Forbes, W. T. M. 1923. The Lepidoptera of New York and neighboring states: primitive forms Microlepidoptera

Pyraloids Bombyces. Cornell Univ. Agric. Exp. Stn. Mem. 68, 729 p. Ithaca, N.Y.

434. Forbes, W. T. M. 1948. Lepidoptera of New York and neighboring states: Geometridae, Sphingidae, Notodontidae, Lymantriidae. Cornell Univ. Agric. Exp. Stn. Mem. 274, 263 p. Ithaca, N.Y.

435. Forbes, W. T. M. 1954. Lepidoptera of New York and neighboring states. Noctuidae. Part III. Cornell Univ. Agric. Exp. Stn. Mem. 329, 433 p. Ithaca, N.Y.

436. Forbush, E. H., and C. H. Fernald. 1896. The gypsy moth, *Porthetria dispar* (Linn.). 495 p. Publ. under direction of State Board of Agric., Wright & Potter Print. Co., State Printers, Boston.

437. Ford, E. J., Jr. 1973. A revision of the genus *Petalium* LeConte in the United States, Greater Antilles, and the Bahamas (Coleoptera: Anobiidae). U.S. Dep. Agric., Tech. Bull. 1467, 40 p.

438. Fowler, M. E. 1958. Oak wilt. U.S. Dep. Agric. For. Serv., For. Pest Leafl. 29, 7 p.

439. Fox, I. 1940. Fleas of eastern United States. 191 p. Iowa State Coll. Press, Ames, Iowa.

440. Fracker, S. B. 1915. The classification of lepidopterous larvae, with ten plates. Ill. Biol. Monogr. 2(1):1-169.

441. Francke-Grosmann, H. 1963. Some new aspects in forest entomology. Ann. Rev. Entomol. 8:415-438.

442. Franclemont, J. G. 1973. Mimallonoidea; Bombycoidea (in part). *In* The moths of America north of Mexico, Fasc. 20.1, p. 1-86. R. B. Dominick and others, eds. E. W. Classey Ltd. & R.B.D. Publ., Inc., London.

443. Franklin, R. T., and H. O. Lund. 1956. The Buprestidae (Coleoptera) of Georgia. Univ. Ga. Coll. Agric., Ga. Agric. Exp. Stn., Tech. Bull. (n.s.) 3, 48 p.

444. Franklin, R. T., and J. W. Taylor. 1970. Biology of *Pachylobius picivorus* (Coleoptera: Curculionidae), in the Georgia Piedmont. Can. Entomol. 102:962-968.

445. Frazier, J. L., T. E. Nebeker, R. F. Mizell, and W. H. Calvert. 1981. Predatory behavior of the clerid beetle *Thanasimus dubius* (Coleoptera: Cleridae) on the southern pine beetle (Coleoptera: Scolytidae). Can. Entomol. 113:35-43.

446. Freeman, T. N. 1958. The Archipinae of North America (Lepidoptera, Tortricidae). Can. Entomol. Suppl. 7, 89 p.

447. Freeman, T. N. 1960. Needle-mining Lepidoptera of pine in North America. Can. Entomol. Suppl. 16, 51 p.

448. Freeman, T. N. 1967. On coniferophagous species of *Choristoneura* (Lepidoptera: Tortricidae) in North America. I. Some new forms of *Choristoneura* allied to *C. fumiferana*. Can. Entomol. 99(5):449-455.

449. Frick, K. E. 1959. Synopsis of the species of the agromyzid leaf miners described from North America (Diptera). Proc. U.S. Natl. Mus. 108(3407): 347-465.

450. Friend, R. B. 1933. The birch leaf-mining sawfly: *Fenusa pumila* Klug. Conn. Agric. Exp. Stn. Bull. 348:289-364.

451. Friend, R. B., and A. B. Carlson. 1937. The control of carpenter ants in telephone poles. Conn. Agric. Exp. Stn. Bull. 403:909-929.

452. Friend, R. B., and A. S. West, Jr. 1933. The European pine shoot moth *(Rhyacionia buoliana* Schiff.) with special reference to its occurrence in the Eli Whitney Forest. Yale Univ. Sch. For. Bull. 37:1-65.

453. Froeschner, R. C. 1954. The grasshoppers and other Orthoptera of Iowa. Iowa State Coll., J. Sci. 29(2):163-354.

454. Frost, C. A. 1908. Notes on *Attelabus rhois* and parasite. Psyche: J. Entomol. 15(2): 26-32.

455. Fulton, B. B. 1915. The tree crickets of New York: life history and bionomics. N.Y. Agric. Exp. Stn., Tech. Bull. 42, 47 p.

456. Funkhouser, W. D. 1923. Family Membracidae. *In* Guide to the insects of Connecticut. Part IV. The Hemiptera or sucking insects of Connecticut. State of Conn., State Geol. & Nat. Hist. Surv. Bull. 34, p. 163-206.

457. Furniss, R. L., and V. M. Carolin. 1977. Western forest insects. U.S. Dep. Agric., Misc. Publ. 1339, 654 p.

458. Furniss, R. L., and R. W. Every. 1957. Carpenter ant [*Camponotus*] control. Oreg. State Coll. Ext. Circ. 627, 6 p.

459. Gagné, J. A., and W. H. Kearby. 1979. Life history, development and insect-host relationships of *Xyleborus celsus* (Coleoptera: Scolytidae) in Missouri. Can. Entomol. 111:295-304.

460. Gagné, R. J. 1978. A systematic analysis of the pine pitch midges, *Cecidomyia* spp. (Diptera: Cecidomyiidae). U.S. Dep. Agric. Sci. Educ. Adm., Tech. Bull. 1575, 18 p.

461. Gahan, A. B. 1918. An interesting new hymenopterous parasite. Can. Entomol. 50(5): 151-152.

462. Gambrell, F. L. 1938. The strawberry root weevil: as a pest of conifers in nursery plantings. J. Econ. Entomol. 31:107-112.

463. Gardiner, L. M. 1960. Descriptions of immature forms and biology of *Xylotrechus colonus* (Fab.) (Coleoptera: Cerambycidae). Can. Entomol. 92(11):820-825.

464. Garman, H. 1916. The locust borer *(Cyllene robiniae)* and other insect enemies of the black locust. Ky. Agric. Exp. Stn., State Univ. Bull. 200, 135 p.

465. Garman, P. 1940. Tetranychidae of Connecticut. Conn. Agric. Exp. Stn. Bull. 431, p. 63-88.

466. Garrett, W. T. 1972. Biosystematics of the oystershell scale, *Lepidosaphes ulmi* (L.) (Homoptera: Diaspididae) in Maryland. Ph.D. Diss., Univ. Md., College Park. 108 p.

467. Gates, D. B., and H. R. Burke. 1972. Review of the gall-inhabiting weevils of the genus *Anthonomus,* with description and biology of a new species (Coleoptera:Curculionidae). Ann. Entomol. Soc. Am. 68:1215-1224.

468. Gentile, A. G., and F. M. Summers. 1958. The biology of San José scale on peaches with special reference to the behavior of males and juveniles. Hilgardia 27(10):269-285.

469. Genung, W. G. 1959. Notes on the syntomid moth *Lymire edwardsi* (Grote) and its control as a pest of *Ficus* in south Florida. Fla. Entomol. 42(1):39-42.

470. George, J. L., and R. T. Mitchell. 1948. Calculations on the extent of spruce budworm control by insectivorous birds. J. For. 46(6):454-455.

471. Gerberg, E. J. 1957. A revision of the New World species of powder-post beetles belonging to the family Lyctidae. U.S. Dep. Agric., Tech. Bull. 1157, 55 p.

472. Gerhold, D., E. J. Schreiner, R. E. McDermott, and J. A. Winieski, eds. 1966. Breeding pest resistant trees: proceedings of a N.A.T.O. and N.S.F. advanced study institute on genetic improvement for disease and insect resistance of forest trees. [Pa. State Univ., Univ. Park, Pa., Aug. 30-Sept. 11, 1964.] 505 p. Pergamon Press, Oxford.

473. Gerson, U., and A. Hazen.

1979. A biosystematic study of *Aspidiotus nerii* Bouché, with the description of one new species. J. Nat. Hist. 13:275-284.

474. Ghent, J. H., C. M. Huber, and R. S. Williams. 1982. Status report of the introduced pine sawfly in the southern Appalachians. U.S. Dep. Agric. For. Serv., State & Priv. For., Southeast. Area, For. Pest Manage. Rep. 83-1-1, 18 p. Atlanta, Ga.

475. Gibbons, C. F., and J. W. Butcher. 1961. The oak skeletonizer, *Bucculatrix ainsliella*, in a Michigan wood lot. J. Econ. Entomol. 54(4):681-684.

476. Gibson, L. P. 1964. Biology and life history of acorn-infesting weevils of the genus *Conotrachelus* (Coleoptera: Curculionidae). Ann. Entomol. Soc. Am. 57(5):521-526.

477. Gibson, L. P. 1965. Systematics of the acorn-infesting weevils *Conotrachelus naso, C. carinifer,* and *C. posticatus* (Coleoptera: Curculionidae). Ann. Entomol. Soc. Am. 58(5): 703-712.

478. Gibson, L. P. 1969. Monograph of the genus *Curculio* in the New World (Coleoptera: Curculionidae). Part I. United States and Canada. Misc. Publ. Entomol. Soc. Am. 6(5): 39-285.

479. Giese, R. L. 1966. The bioecology of *Corthylus columbianus* Hopk. *In* Material und Organismen: Internationales Symposium Berlin-Dahlem 1965. p. 361-370. [Suppl. 1, Holz und Organismen, Heft 1.] Duncker & Humblot, Berlin.

480. Giese, R. L. 1967. The Columbian timber beetle, *Corthylus columbianus* (Coleoptera: Scolytidae). V. A description of the mycetangia. Can. Entomol. 99(1):54-58.

481. Giese, R. L. 1981. Low temperature effects on the egg stage. *In* The gypsy moth: research toward integrated pest management. C. C. Doane and M. L. McManus, eds. U.S. Dep. Agric. For. Serv., Sci. and Educ. Agency, and Anim. and Plant Health Insp. Serv. Tech. Bull. 1584, p. 150-154.

482. Giese, R. L., and D. M. Benjamin. 1959. The biology and ecology of the balsam gall midge in Wisconsin. For. Sci. 5(2):193-208.

483. Giese, R. L., and D. M. Benjamin. 1964. The insect complex associated with maple blight. *In* Studies of maple blight. Univ. Wis., Res. Bull. 250, Part II, p. 20-57.

484. Gill, J. B. 1917. The pecan leaf case-bearer. U.S. Dep. Agric. Bull. 571, 28 p.

485. Gill, S. A., D. R. Miller, and J. A. Davidson. 1982. Bionomics and taxonomy of the euonymus scale, *Unaspis euonymi* (Comstock), and detailed biological information on the scale in Maryland. Univ. Md. Agric. Exp. Stn., Misc. Publ. 969, 36 p.

486. Gimpel, W. F., Jr., D. R. Miller, and J. A. Davidson. 1974. A systematic revision of the wax scales, genus *Ceroplastes*, in the United States (Homoptera; Coccoidea; Coccidae). Univ. Md. Agric. Exp. Stn., Misc. Publ. 841, 85 p.

487. Girth, H. B., and E. E. McCoy. 1946. *Neodiprion sertifer* (Geoff.), a sawfly injurious to pines in New Jersey, and parasite work for its control. N.J. Dep. Agric. Circ. 363, 18 p.

488. Glaser, J. D. 1976. The biology of *Dynastes tityus* (Linn.) in Maryland (Coleoptera: Scarabaeidae). Coleopterists Bull. 30:133-138.

489. Godwin, P. A., H. D. Rule, and W. E. Waters. 1964. Some effects of gamma irradiation on the gypsy moth, *Porthetria dis-*

par. J. Econ. Entomol. 57(6):986-990.

490. Godwin, P. A., H. T. Valentine, and T. M. ODell. 1982. Identification of *Pissodes strobi, P. approximatus,* and *P. nemorensis* (Coleoptera: Curculionidae), using discriminant analysis. Ann. Entomol. Soc. Am. 75:599-603.
491. Goyer, R. A., G. J. Lenhard, T. E. Nebeker, and L. D. Jarrard. 1980. How to identify common insect associates of the southern pine beetle. U.S. Dep. Agric., Comb. For. Pest Res. & Dev. Program, Agric. Handb. 563, 33 p.
492. Graham, K. 1963. Concepts of forest entomology. 388 p. Reinhold Publ. Corp., New York.
493. Graham, S. A. 1937. The walking stick as a forest defoliator. Univ. Mich. Sch. For. & Conserv. Circ. 3, 28 p.
494. Graham, S. A. 1939. Principles of forest entomology. 2d ed. 410 p. McGraw-Hill Book Co., Inc., New York.
495. Graham, S. A. 1956. Hazard rating of stands containing balsam fir according to expected injury by spruce budworm. Univ. Mich. Dep. For., Mich. For. 13, 2 p.
496. Graham, S. A. 1956. The larch sawfly in the Lake States. For. Sci. 2(2):132-160.
497. Graham, S. A., and L. B. Baumhofer. 1927. The pine tip moth in the Nebraska National Forest. J. Agric. Res. 35(4):323-333.
498. Graham, S. A., and L. W. Orr. 1940. The spruce budworm in Minnesota. Univ. Minn. Agric. Exp. Stn., Tech. Bull. 142, 27 p.
499. Gray, I. E. 1946. Observations on the life history of the horned passalus. Am. Midl. Natl. 35(3):725-746.
500. Green, G. W. 1962. Low winter temperatures and the European pine shoot moth, *Rhyacionia buoliana* (Schiff.) in Ontario. Can. Entomol. 94(3):314-336.
501. Green, H. B. 1952. Biology and control of the imported fire ant in Mississippi. J. Econ. Entomol. 45(4):593-597.
502. Greenbank, D. O. 1956. The role of climate and dispersal in the initiation of outbreaks of the spruce budworm in New Brunswick. I. The role of climate. Can. J. Zool. 34(5): 453-476.
503. Greenbank, D. O., G. W. Shaefer, and R. C. Rainey. 1980. Spruce budworm (Lepidoptera: Tortricidae) moth flight and dispersal: new understanding from canopy observations, radar, and aircraft. Mem. Entomol. Soc. Can. 110, 49 p.
504. Grimble, D. G., and R. G. Newell. 1973. Damage to sugar maple in New York State from saddled prominent defoliation. State Univ. N.Y., Coll. Environ. Sci. & For., Appl. For. Res. Inst., Res. Note 7, 4 p.
505. Griswold, C. L. 1939. Introduced pine sawfly. J. Econ. Entomol. 32:467-468.
506. Griswold, C. L. 1956. Transmission of the oak wilt fungus by *Pseudopityophthorus minutissimus* (Zimm.). J. Econ. Entomol. 49(4):560-561.
507. Griswold, C. L. 1958. Transmission of the oak wilt fungus by certain woodland-inhabiting Drosophilidae. J. Econ. Entomol. 51(5):733-735.
508. Gurevitz, E. 1976. Contribution of the study of Scolytidae: II population dynamics of *Scolytus (Ruguloscolytus) mediterraneus* Eggers in Israel. Ann. Zool. Ecol. Anim. 8:53-68.
509. Gurney, A. B. 1951. Praying mantids of the United States, native and introduced. Smithson. Inst., Annu. Rep. 1950, p. 339-362.
510. Haack, R. A., and D. M. Benjamin. 1982. The biology and ecology of the twolined chestnut

borer, *Agrilus bilineatus* (Coleoptera: Buprestidae), on oaks, *Quercus* spp., in Wisconsin. Can. Entomol. 114:385-396.

511. Haack, R. A., D. M. Benjamin, and B. A. Schuh. 1981. Observations on the biology of *Phasgonophora sulcata* (Hymenoptera: Chalcididae), a larval parasitoid of the twolined chestnut borer, *Agrilus bilineatus* (Coleoptera: Buprestidae), in Wisconsin. Great Lakes Entomol. 14:113-116.

512. Hagen, K. S. 1962. Biology and ecology of predaceous Coccinellidae. Annu. Rev. Entomol. 7:289-326.

513. Hain, F. P. [1981]. Sampling and predicting population trends. *In* The southern pine beetle. R. C. Thatcher, J. L. Searcy, J. E. Coster, and G. D. Hertel, eds. U.S. Dep. Agric. For. Serv. and Sci. and Educ. Admin. Tech. Bull. 1631, p. 106-135.

514. Haliburton, W. 1951. On the habits of the elm bark borer, *Physocneumum brevilineum* (Say); (Coleoptera: Cerambycidae). Can. Entomol. 83(2):36-38.

515. Hall, R. C. 1942. Control of the locust borer. U.S. Dep. Agric. Circ. 626, 20 p.

516. Hamel, D. R. 1980. Forest and forest products pests. *In* Guidelines for the control of insects and mite pests of foods, fibers, feeds, ornamentals, livestock, households, forests, and forest products. P. H. Schwartz and D. R. Hamel, eds. U.S. Dep. Agric., Sci. and Educ. Admin., and For. Serv., Agric. Handb. 571, p. 748-796.

517. Hamilton, C. C. 1942. The taxus mealybug, *Pseudococcus cuspidatae* Rau. J. Econ. Entomol. 35(2):173-175.

518. Hamilton, K. G. A. 1982. Taxonomic changes in *Aphrophora* (Rhyncota: Homoptera: Cercopidae). Can. Entomol. 114:1185-1189.

519. Hamilton, R. W. 1971. The genus *Pselaphorhynchites* (Coleoptera: Rhynchitidae) in America north of Mexico. Ann. Entomol. Soc. Am. 64: 982-996.

520. Hamilton, R. W. 1979. Taxonomic use of endophallic structures in some Attelabidae and Rhynchitidae of America north of Mexico (Coleoptera: Curculionidae), with notes on nomenclature. Ann. Entomol. Soc. Am. 72:29-34.

521. Hamon, A. B., and M. Kosztarab. 1979. Morphology and systematics of the first instars of the genus *Cerococcus* (Hemoptera: Coccoidea: Cerococcidae). *In* Studies on the morphology and systematics of scale insects—No. 11. Va. Polytech. Inst. & State Univ., Res. Div. Bull. 146, p. 1-22.

522. Hamon, A. B., P. L. Lambdin, and M. Kosztarab. 1976. I. Life history and morphology of *Kermes kingi* in Virginia (Homoptera: Coccoidea: Kermesidae). *In* Studies on the morphology and systematics of scale insects—No. 8. Va. Polytech. Inst. & State Univ., Res. Div. Bull. 111, p. 1-31.

523. Hanson, J. B., and D. M. Benjamin. 1967. Biology of *Phytobia setosa*, a cambium miner of sugar maple. J. Econ. Entomol. 60(5):1351-1355.

524. Harlan, D. S. 1974. White fringed beetles: control of larvae in nursery containers and phytotoxicity of Abates. J. Econ. Entomol. 67:804-805.

525. Harman, D. M., and H. M. Kulman. 1967. An annotated list. Parasites and predators of the white-pine weevil, *Pissodes strobi* (Peck). Univ. Md., Nat. Resour. Inst. Contrib. 323, 35 p.

526. Harman, D. M., and H. M. Kulman, eds. 1973. A world

survey of the parasites and predators of the genus *Rhyacionia*, Parts I-IV. Univ. Md., Nat. Resour. Inst. Contrib. 527, 179 p.

527. Harper, J. D., and L. P. Abrahamson. 1979. Forest tent caterpillar control with aerially applied formulations of *Bacillus thuringiensis* and Dimilin. J. Econ. Entomol. 72:74-77.

528. Harrell, M. O., D. M. Benjamin, J. G. Berbee, and T. R. Burkot. 1982. Consumption and utilization of leaf tissue of tissue-cultured *Populus* x *euramericana* by the cottonwood leaf beetle, *Chrysomela scripta* (Coleoptera: Chrysomelidae). Can. Entomol. 114:743-749.

529. Harris, E. C., and J. M. Taylor. 1960. Powder-post beetles for test purposes. Timber Technol. 68(2251): 193-195, 197.

530. Harris, J. W. E., and H. C. Coppel. 1967. The poplar- and willow-borer, *Sternochetus (Cryptorhyncus) lapathi* (Coleoptera: Curculionidae), in British Columbia. Can. Entomol. 99:411-418.

531. Hartzell, A. 1957. Red pine scale with special reference to its host plants and coldhardiness. Contrib. Boyce Thompson Inst. 18(10): 421-428.

532. Haseman, L. 1940. The walnut caterpillar. Univ. Mo. Coll. Agric., Agric. Exp. Stn. Bull. 418, 14 p.

533. Haseman, L., and S. R. McLane. 1940. The history and biology of the juniper midge *(Contarinia juniperina* Felt). Ann. Entomol. Soc. Am. 33(4):612-615.

534. Hastings, A. R., and P. A. Godwin. 1970. White-pine weevil. U.S. Dep. Agric. For. Serv., For. Pest Leafl. 21 rev., 7 p.

535. Hastings, F. L., and J. E. Coster, eds. 1981. Field and laboratory evaluations of insecticides for southern pine beetle control. U.S. Dep. Agric. For. Serv., Gen. Tech. Rep. SE-21, 40 p. Southeast. For. Exp. Stn., Asheville, N.C.

536. Haverty, M. I. 1976. Termites. Pest Control 44(5):12-17, 46-47, 49.

537. Hay, C. J. 1958. Life history and control of a root collar borer *(Euzophera ostricolorella* Hulst) in yellow-poplar. J. Econ. Entomol. 51(2):251-252.

538. Hay, C. J. 1962. Reduce red oak borer damage silviculturally. U.S. Dep. Agric. For. Serv., Central States For. Exp. Stn., Stn. Note 154, 2 p. [North Central For. Exp. Stn., St. Paul, Minn.]

539. Hay, C. J. 1969. The life history of a red oak borer and its behavior in red, black, and scarlet oak. Proc. North Cent. Branch Entomol. Soc. Am. 24(2): 125-127.

540. Hay, C. J., and R. C. Morris. 1961. Carpenterworm. U.S. Dep. Agric. For. Serv., For. Pest Leafl. 64, 8 p.

541. Haynes, D. L., and J. W. Butcher. 1962. Studies on the ecology of European pine shoot moth larvae in Michigan. Ecology 43(1):96-107.

542. Hebard, M. 1931. The Orthoptera of Kansas. Proc. Acad. Nat. Sci. Phila. 83: 119-227.

543. Hebard, M. 1932. The Orthoptera of Minnesota. Univ. Minn. Agric. Exp. Stn., Tech. Bull. 85, 61 p.

544. Hebard, M. 1934. The Dermaptera and Orthoptera of Illinois. Ill. Dep. Regist. & Educ., Div. Nat. Hist. Surv. Bull. 20 (Artic. 3):125-279.

545. Hebard, M. 1936. Orthoptera of North Dakota. N.Dak. Agric. Exp. Stn. Bull. 284—Tech., 69 p.

546. Hedden, R. L., S. J. Barras, and J. E. Coster, eds. 1981. Hazard-rating systems in forest insect pest management: symposium

proceedings. [Athens, Ga., July-August 1980.] U.S. Dep. Agric. For. Serv., Gen. Tech. Rep. WO-27, 169 p. Washington, D.C.

547. Hedlin, A. F., H. O. Yates III, D. Cibrián Tovar, B. H. Ebel, T. W. Koerber, and E. P. Merkel. 1980. Cone and seed insects of North American conifers. 122 p. Can. For. Serv., U.S. Dep. Agric. For. Serv., Secr. Agric. Recur. Hidraul. Mexico.

548. Heikkenen, H. J. 1963. Influence of site and other factors on damage by the European pine shoot moth. Ph.D. Diss., Univ. Mich., Ann Arbor. 137 p.

549. Heimpel, A. M. 1967. A critical review of *Bacillus thuringiensis* var. *thuringiensis* Berliner and other crystalliferous bacteria. Annu. Rev. Entomol. 12: 287-322.

550. Heimpel, A. M., and T. A. Angus. 1963. Diseases caused by certain sporeforming bacteria. *In* Insect pathology: an advanced treatise, vol. 2. p. 21-73. E. A. Steinhaus, ed. Academic Press, New York.

551. Heinrich, C. 1923. Revision of the North American moths of the subfamily Eucosminae of the family Olethreutidae. U.S. Natl. Mus. Bull. 123, 298 p.

552. Heinrich, C. 1926. Revision of the North American moths of the subfamilies Laspeyresiinae and Olethreutinae. U.S. Natl. Mus. Bull. 132, 216 p.

553. Heinrich, C. 1956. American moths of the subfamily Phycitinae. U.S. Natl. Mus. Bull. 207, 581 p.

554. Heinrichs, E. A., and H. E. Thompson. 1968. The biology of *Choristoneura houstonana* (Lepidoptera: Tortricidae), a pest of *Juniperus* species. Can. Entomol. 100(7):750- 763.

555. Helfer, J. R. 1941. A revision of the genus *Buprestis* of North America north of Mexico (Coleoptera, Buprestidae). Entomol. Am. (n.s.) 21(3):123-198.

556. Heller, R. C., R. C. Aldrich, and W. F. Bailey. 1959. An evaluation of aerial photography for detecting southern pine beetle damage. Photogramm. Eng. 25(4):595-606.

557. Heller, R. C., J. L. Bean, and J. W. Marsh. 1952. Aerial survey of spruce budworm damage in Maine in 1950. J. For. 50(1):8-11.

558. Heller, R. C., J. H. Lowe, Jr., R. C. Aldrich, and F. P. Weber. 1967. A test with large scale aerial photographs to sample balsam woolly aphid damage in the Northeast. J. For. 65(1):10-18.

559. Heller, R. C., and D. C. Schmiege. 1962. Aerial survey techniques for the spruce budworm in the Lake States. J. For. 60(8):525-532.

560. Herman, S. G., and J. B. Bulger. 1979. Effects of a forest application of DDT on nontarget organisms. Wildl. Monogr. 69, 62 p.

561. Herrick, G. W. 1910. The snow-white linden moth. Cornell Univ. Agric. Exp. Stn. Bull. 286, p. 49-61.

562. Hess, A. D. 1940. The biology and control of the round-headed apple-tree borer, *Saperda candida* Fabricius. N.Y. State Agric. Exp. Stn. Bull. 688, 93 p.

563. Hetrick, L. A. 1941. Life history studies of *Neodiprion americanum* (Leach). J. Econ. Entomol. 34(3):373-377.

564. Hetrick, L. A. 1956. Life history studies of five species of *Neodiprion* sawflies. For. Sci. 2(3):181-185.

565. Hetrick, L. A. 1959. Ecology of the pine sawfly, *Neodiprion excitans* (Rohwer) (Hymenoptera, Diprionidae). Fla. Entomol. 42(4):159-162.

566. Hickin, N. E. 1971. Termites: a world problem. 232 p. Hutchinson & Co., Ltd., London.

567. Hickin, N. E. 1975. The insect factor in wood decay: An account of wood-boring insects with particular reference to timber indoors. 3d ed. 383 p. Assoc. Bus. Prog., London.

568. Highland, H. A. 1956. The biology of *Ferrisiana virgata*, a pest of azaleas. J. Econ. Entomol. 49(2):276-277.

569. Highland, H. A. 1964. Life history of *Asphondylia ilicicola* (Diptera: Cecidomyiidae), a pest of American holly. J. Econ. Entomol. 57(1):81-83.

570. Hildahl, V., and W. A. Reeks. 1960. Outbreaks of the forest tent caterpillar, *Malacosoma disstria* Hbn., and their effects on stands of trembling aspen in Manitoba and Saskatchewan. Can. Entomol. 92(3):199-209.

571. Hill, C. H. 1952. The biology and control of the scurfy scale on apples in Virginia. Va. Polytech. Inst., Agric. Exp. Stn., Tech. Bull. 119, 39 p.

572. Hines, J. W., and H. J. Heikkenen. 1977. Beetles attracted to several Virginia pine *(Pinus virginiana* Mill.). Environ. Entomol. 6:123-127.

573. Hite, J. M., W. J. Gladney, J. L. Lancaster, Jr., and W. H. Whitcomb. 1966. Biology of the brown recluse spider. Ark. Agric. Exp. Stn. Bull. 711, 26 p.

574. Hodges, R. W. 1971. Sphingoidea. *In* The moths of America north of Mexico, Fasc. 21. p. 1-158. R. B. Dominick, and others, eds. E. W. Classey Ltd. and R. B. D. Publ., Inc., London.

575. Hodges, R. W., T. Dominick, D. R. Davis, and others. 1983. Checklist of the Lepidoptera of America north of Mexico. 284 p. E. W. Classey Ltd. and The Wedge Entomol. Res. Found., London.

576. Hodson, A. C. 1939. *Sarcophaga aldrichi* Parker as a parasite of *Malacosoma disstria* Hbn. J. Econ. Entomol. 32(3):396-401.

577. Hodson, A. C. 1941. An ecological study of the forest tent caterpillar, *Malacosoma disstria* Hbn., in northern Minnesota. Univ. Minn. Agric. Exp. Stn., Tech. Bull. 148, 55 p.

578. Hodson, A. C. 1942. Biological notes on the basswood leafminer, *Baliosus ruber* (Weber). J. Econ. Entomol. 35(4): 570-753.

579. Hodson, A. C., and C. J. Weinman. 1945. Factors affecting recovery from diapause and hatching of eggs of the forest tent caterpillar, *Malacosoma disstria* Hbn. Univ. Minn. Agric. Exp. Stn., Tech. Bull. 170, 31 p.

580. Hodson, A. C., and P. J. Zehngraff. 1946. Budworm control in jack pine by forest management. J. For. 44(3): 198-200.

581. Hofacker, T. H., and R. C. Loomis. 1982. Forest insect and disease conditions in the United States 1981. 51 p. U.S. Dep. Agric. For. Serv., For. Pest Manage., Washington, D.C.

582. Hoff, C. C. 1949. The pseudoscorpions of Illinois. Bull. Ill. Nat. Hist. Surv. 24 (Artic. 4):413-498.

583. Hoffard, W. H., and R. T. Marshall. 1978. How to identify and control the sugar maple borer. U.S. Dep. Agric., For. Serv., Northeast. Area, State & Priv. For. NA-GR-1, 8 p. Delaware, Ohio.

584. Hoffmann, C. H. 1939. Observations on the biology of *Saperda tridentata* Oliv. and *Magdalis armicollis* Say (Coleoptera). J. Econ. Entomol. 32(6):848-851.

585. Holden, C. 1982. Bald eagles on the rise. Science 216:968.

586. Holland, W. J. 1931. The butterfly book. Rev. ed. 424 p. Doubleday, Doran & Co., Inc.,

Garden City, N.Y.
587. Holland, W. J. 1968. The moth book: a popular guide to a knowledge of the moths of North America. Rev. ed. 479 p. Dover Publ., Inc., New York.
588. Honigberg, B. M. 1970. Protozoa associated with termites and their role in digestion. *In* Biology of termites, vol. 2. p. 1-36. K. Krishna and F. M. Weesner, eds. Academic Press, New York and London.
589. Hood, C. E. 1940. Life history and control of the imported willow leaf beetle. U.S. Dep. Agric. Circ. 572, 10 p.
590. Hopkins, A. D. 1899. Report on investigations to determine the cause of unhealthy conditions of the spruce and pine from 1880-1893. W. Va. Agric. Exp. Stn. Bull. 56, 461 p.
591. Hopkins, A. D. 1909. Practical information on the scolytid beetles of North American forests. I. Barkbeetles of the genus *Dendroctonus*. U.S. Dep. Agric. Bur. Entomol. Bull. 83, 169 p.
592. Hopping, G. R. 1963. The natural groups of species in the genus *Ips* De Geer (Coleoptera: Scolytidae) in North America. Can. Entomol. 95(5):508-516.
593. Hopping, G. R. 1963. The North American species in Group I of *Ips* De Geer (Coleoptera: Scolytidae). Can. Entomol. 95(10):1091-1096.
594. Hopping, G. R. 1963. The North American species in Groups II and III of *Ips* De Geer (Coleoptera: Scolytidae). Can. Entomol. 95(11):1202-1210.
595. Hopping, G. R. 1964. The North American species in Groups IV and V of *Ips* De Geer (Coleoptera: Scolytidae). Can. Entomol. 96(7):970-978.
596. Hopping, G. R. 1965. The North American species in Group VI of *Ips* De Geer (Coleoptera: Scolytidae). Can. Entomol. 97(5):533-541.
597. Hopping, G. R. 1965. The North American species in Group VII of *Ips* De Geer (Coleoptera: Scolytidae). Can. Entomol. 97(2):193-198.
598. Hopping, G. R. 1965. The North American species in Group VIII of *Ips* De Geer (Coleoptera: Scolytidae). Can. Entomol. 97(2):159-172.
599. Hopping, G. R. 1965. North American species in Group IX of *Ips* De Geer (Coleoptera: Scolytidae). Can. Entomol. 97(4):422-434.
600. Hopping, G. R. 1965. The North American species in Group X of *Ips* De Geer (Coleoptera: Scolytidae). Can. Entomol. 97(8):803-809.
601. Hopping, R. 1921. A review of the genus *Monochamus* Serv. (Cerambycidae, Coleoptera). Can. Entomol. 53(11):252-258.
602. Horsfall, W. R. 1943. Biology and control of common blister beetles in Arkansas. Ark. Agric. Exp. Stn. Bull. 436, 55 p.
603. Hottes, F. C., and T. H. Frison. 1931. The plant lice; or Aphiidae; of Illinois. Ill. Dep. Regist. & Educ., Div. Nat. Hist. Surv. Bull. 19(Artic. 3):121-447.
604. Hough, W. S. 1925. Biology and control of Comstock's mealy bug on the umbrella catalpa. Va. Polytech. Inst., Va. Agric. Exp. Stn., Tech. Bull 29, 27 p.
605. Houser, J. S. 1918. Destructive insects affecting Ohio shade and forest trees. Ohio Agric. Exp. Stn. Bull. 332, p. 161-487.
606. Houseweart, M. W. 1982. Insect pest of artificial regeneration in Maine. 1 p. CFRU College of Forest Resources, Univ. Maine, Orono.
607. Houseweart, M. W., and H. M. Kulman. 1976. Life tables of the yellowheaded spruce sawfly, *Pikonema alaskensis* (Rohwer) (Hymenoptera: Tenthredinidae) in Minnesota. Environ. Entomol. 5:859-867.
608. Houston, D. R. 1981. Forest

stand relationships. *In* The gypsy moth: research toward integrated pest management. C. C. Doane and M. L. McManus, eds. U.S. Dep. Agric. For. Serv., Sci. and Educ. Agency, and Anim. and Plant Health Insp. Serv. Tech. Bull. 1584, p. 267-294.

609. Howard, L. O. 1897. A study in insect parasitism: A consideration of the parasites of the white-marked tussock moth, with an account of their habits and interrelations, and with descriptions of new species. U.S. Dep. Agric., Div. Entomol., Tech. Ser. 5, 57 p.

610. Howard, L. O., and F. H. Chittenden. 1916. The bagworm, an injurious shade-tree insect. U.S. Dep. Agric., Farmers' Bull. 701, 11 p.

611. Howard, L. O., and F. H. Chittenden. 1916. The catalpa sphinx. U.S. Dep. Agric., Farmers' Bull. 705, 9 p.

612. Howard, L. O., and F. H. Chittenden. 1916. The leopard moth: a dangerous imported insect enemy of shade trees. U.S. Dep. Agric., Farmers' Bull. 708, 10 p.

613. Howard, L. O., and W. F. Fiske. 1911. The importation into the United States of the parasites of the gipsy moth and the brown-tail moth: a report of progress, with some consideration of previous and concurrent efforts of this kind. U.S. Dep. Agric. Bur. Entomol. Bull. 91, 344 p.

614. Howe, W. H., ed. 1975. The butterflies of North America. 633 p. Doubleday & Co., Inc., Garden City, N.Y.

615. Howell, J. O., and M. Kosztarab. 1972. Studies on the morphology and systematics of scale insects—No. 4: morphology and systematics of the adult females of the genus *Lecanodiaspis* (Homoptera: Coccoidea: Lecanodiaspididae). Va. Polytech. Inst. & State Univ., Res. Div. Bull. 70, 248 p.

616. Howell, J. O., M. L. Williams, and M. Kosztarab. 1971. Studies on the morphology and systematics of scale insects—No. 3: morphology and systematics of *Cerococcus parrotti* (Hunter) with notes on its biology (Homoptera: Coccoidea: Asterolecaniidae). Va. Polytech. Inst. & State Univ., Res. Div. Bull. 64, 23 p.

617. Howse, P. E. 1970. Termites: a study in social behaviour. 150 p. Hutchinson Univ. Libr., London.

618. Hoy, M. A. 1976. Establishment of gypsy moth parasitoids in North America: an evaluation of possible reasons for establishment or non-establishment. *In* Perspectives in forest entomology. p. 215-232. J. F. Anderson and H. K. Kaya, eds. Academic Press, New York.

619. Hubbard, H. G. 1897. The ambrosia beetles of the United States. U.S. Dep. Agric., Entomol. Bull. (n.s.) 7, p. 9-35.

620. Hubbard, H. G., and T. Pergande. 1898. A new coccid on birch. U.S. Dep. Agric., Div. Entomol. Bull. (n.s.) 18, p. 13-26.

621. Huffaker, C. B., and P. S. Messenger, eds. 1976. Theory and practice of biological control. 788 p. Academic Press, Inc., New York.

622. Hughes, K. M. 1957. An annotated list and bibliography of insects reported to have virus diseases. Hilgardia 26(14): 597-629.

623. Ignoffo, C. M., and A. A. Granovsky. 1961. Life history and gall development of *Mordwilkoja vagabunda* (Homoptera: Aphidae) on *Populus deltoides*. Ann. Entomol. Soc. Am. 54(4):486-499.

624. Ikeda, T., F. Matsumura, and D. M. Benjamin. 1977. Mechanism of feeding discrimination

between matured and juvenile foliage by two species of pine sawflies. J. Chem. Ecol. 6:677-694.

625. Imms, A. D. 1948. A general textbook of entomology: including the anatomy, physiology, development and classification of insects. 7th ed. 727 p. E. P. Dutton & Co., Inc., New York.

626. Inscoe, M. N., and J. R. Plimmer. 1981. Chemistry of isolation, identification and synthesis. *In* The gypsy moth: research toward integrated pest management. C. C. Doane and M. L. McManus, eds. U.S. Dep. Agric. For. Serv., Sci. and Educ. Agency, and Anim. and Plant Health Insp. Serv. Tech. Bull. 1584, p. 533-536.

627. Isler, D. A., and J. S. Yuill. 1956. Research on the control of forest insects by aircraft. J. Econ. Entomol. 49(1):92-94.

628. Ives, W. G. H. 1973. Heat units and outbreaks of the forest tent caterpillar, *Malacosoma disstria* (Lepidoptera: Lasiocampidae). Can. Entomol. 105:529-543.

629. Ives, W. G. H. 1976. The dynamics of larch sawfly (Hymenoptera: Tenthredinidae) populations in southeastern Manitoba. Can. Entomol. 108(7):701-730.

630. Ives, W. G. H. 1981. Environmental factors affecting 21 forest insect defoliators in Manitoba and Saskatchewan, 1945-69. Environ. Can., Can. For. Serv., North. For. Res. Cent. Inform. Rep. NOR-X-233, 142 p.

631. Ives, W. G. H., and R. M. Prentice. 1958. A sequential sampling technique for surveys of the larch sawfly. Can. Entomol. 90(6):331-338.

632. Ives, W. G. H., and G. L. Warren. 1965. Sequential sampling for white grubs. Can. Entomol. 97(6):596-604.

633. Jacobson, M. 1972. Insect sex pheromones. 382 p. Academic Press, New York.

634. Jacobson, M., M. Beroza, and W. A. Jones. 1961. Insect sex attractants. I. The isolation, identification, and synthesis of the sex attractant of the gypsy moth. J. Am. Chem. Soc. 83(23):4819-4824.

635. Jaques, H. E. 1951. How to know the beetles. 372 p. Wm. C. Brown Co., Dubuque, Iowa.

636. Jaynes, H. A., and A. T. Drooz. 1952. The importance of parasites in the spruce budworm infestations in New York and Maine. J. Econ. Entomol. 45(6):1057-1061.

637. Jaynes, H. A. , and P. A. Godwin. 1957. Sterilization of the white-pine weevil with gamma radiation. J. Econ. Entomol. 50(4):393-395.

638. Jennings, D. T., F. B. Knight, S. C. Hacker, and M. E. McKnight. 1979. Spruce budworms bibliography: With author and key word indices. Life Sci. & Agric. Exp. Stn., Misc. Rep. 213, 687 p. Canada/U.S. Spruce Budworms Program, Sch. For. Resour., Univ. Maine, Orono.

639. Jensen, D. D. 1957. Parasites of the Psyllidae. Hilgardia 27(2):71-99.

640. Jeppson, L. R., H. H. Keifer, and E. W. Baker. 1975. Mites injurious to economic plants. 614 p. Univ. Calif. Press, Berkeley.

641. Jobin, L., and A. Caron. 1982. Results of aerial treatments with Dimilin® and *Bacillus thuringiensis* for gypsy moth *(Lymantria dispar* [L.]) control in Quebec. Can. For. Serv. Res. Notes 2:18-20.

642. Johnson, P. C. 1958. Spruce spider mite infestations in northern Rocky Mountain Douglas-fir forests. U.S. Dep. Agric. For. Serv., Res. Pap. 55, 14 p. Intermt. For. & Range Exp.

Stn., Ogden, Utah.
643. Johnson, W. G. 1896. Descriptions of five new species of scale insects, with notes. Bull. Ill. State Lab. Nat. Hist. 4 (Artic. 13):380-395.
644. Johnson, W. T., and H. H. Lyon. 1976. Insects that feed on trees and shrubs. 464 p. Cornell Univ. Press, Ithaca, N.Y.
645. Johnston, H. R., V. K. Smith, and R. H. Beal. 1972. Subterranean termites, their prevention and control in buildings. U.S. Dep. Agric. Home & Garden Bull. 64 rev., 30 p.
646. Jones, F. M., and H. B. Parks. 1928. The bagworms of Texas. Texas Agric. Exp. Stn. Bull. 382, 36 p.
647. Jones, S. 1981. White-pine pest gets "the sting." Am. For. 87(12):22-25, 62.
648. Kabir, A. K. M. F., and R. L. Giese. 1966. The Columbian timber beetle, *Corthylus columbianus* (Coleoptera: Scolytidae). I. Biology of the beetle. Ann. Entomol. Soc. Am. 59(5): 883-894.
649. Kabir, A. K. M. F., and R. L. Giese. 1966. The Columbian timber beetle, *Corthylus columbianus* (Coleoptera: Scolytidae). II. Fungi and staining associated with the beetle in soft maple. Ann. Entomol. Soc. Am. 59(5):894-902.
650. Kapler, J. E., and D. M. Benjamin. 1960. The biology and ecology of the red-pine sawfly in Wisconsin. For. Sci. 6(3):253-268.
651. Kaston, B. J. 1939. The native elm bark beetle, *Hylurgopinus rufipes* (Eichhoff), in Connecticut. Conn. Agric. Exp. Stn. Bull. 420, 39 p.
652. Kaya, H. K. 1975. Persistance of spores of *Pleistophora schubergi* (Cnidospora: Microsporidia) in the field and their application in microbial control. J. Invert. Pathol. 26:329-332.
653. Kaya, H. K., and J. F. Anderson. 1973. Elm spanworm egg distribution in a Connecticut hardwood forest. Ann. Entomol. Soc. Am. 56(4)825-829.
654. Kaya, H. K., and J. F. Anderson. 1976. Alternate hosts of the elm spanworm egg parasitoid, *Ooencyrtus ennomophagus*. Ann. Entomol. Soc. Am. 69:35-37.
655. Kaya, H. K., and J. F. Anderson. 1976. Biotic mortality factors in dark tussock moth populations in Connecticut. Environ. Entomol. 5:1141-1145.
656. Kearby, W. H. 1975. Variable oakleaf caterpillar larvae secrete formic acid that causes skin lesions (Lepidoptera: Notodontidae). J. Kans. Entomol. Soc. 48:280-282.
657. Kearby, W. H., and D. M. Benjamin. 1964. The biology and ecology of the red-pine needle midge and its role in fall browning of red pine foliage. Can. Entomol. 96(10):1313-1322.
658. Kearby, W. H., and D. M. Benjamin. 1969. Life history and damage of the pine tip weevil, *Hylobius rhizophagus*, in Wisconsin. Ann. Entomol. Soc. Am. 62:838-843.
659. Keen, F. P. 1943. Ponderosa pine tree classes redefined. J. For. 41(4):249-253.
660. Kegg, J. D. 1973. Oak mortality caused by repeated gypsy moth defoliations in New Jersey. J. Econ. Entomol. 66(3):639-641.
661. Keifer, H. H. 1946. A review of North American economic Eriophyid mites. J. Econ. Entomol. 39(5):563-570.
662. Kennedy, H. E., J. D. Solomon, and R. M. Kinard. 1981. Twig girdler, *Oncideres cingulata* (Say), attacks terminals of plantation-managed pecans. U.S. Dep. Agric., For. Serv. Res. Note SO-263, 4 p. South. For. Exp. Stn., New Orleans, La.
663. Kerr, T. W., Jr. 1949. The arbor-

vitae weevil, *Phyllobius intrusus* Kono. R.I. Agric. Exp. Stn. Bull. 305, 30 p.

664. Kilgore, W. W., and R. L. Doutt, eds. 1967. Pest control: biological, physical, and selected chemical methods. 477 p. Academic Press, New York and London.

665. King, E. G., Jr., and W. T. Spink. 1969. Foraging galleries of the Formosan subterranean termite, *Coptotermes formosanus*, in Louisiana. Ann. Entomol. Soc. Am. 62(3): 536-542.

666. King, W. V., G. H. Bradley, and T. E. McNeel. 1944. The mosquitoes of the Southeastern States. U.S. Dep. Agric., Misc. Publ. 336 rev., 96 p.

667. Kinsey, A. C. 1920. Article VI. Life histories of American Cynipidae. Bull. Am. Mus. Nat. Hist. 42:319-357

668. Kinsey, A. C. 1920. Article VII. Phylogeny of Cynipid genera and biological characteristics. Bull. Am. Mus. Nat. Hist. 42:357-402.

669. Kinsey, A. C. 1935. The economic importance of the Cynipidae. J. Econ. Entomol. 28(1):86-91.

670. Kissinger, D. G. 1964. Curculionidae of America north of Mexico: a key to the genera. 143 p. Taxonomic Publ., South Lancaster, Mass.

671. Klein, M. G., and H. C. Coppel. 1969. The pine chrysomelid, *Glyptoscelis pubescens*, in northwestern Wisconsin. Ann. Entomol. Soc. Am. 62:1-7.

672. Klots, A. B. 1951. A field guide to the butterflies of North America, east of the Great Plains. 349 p. Houghton Mifflin Co., Boston.

673. Knight, F. B. 1958. The effects of woodpeckers on populations of the Engelmann spruce beetle. J. Econ. Entomol. 51(5): 603-607.

674. Knight, F. B., and H. J. Heikkenen. 1980. Principles of forest entomology. 5th ed. 461 p. McGraw-Hill Book Co., New York.

675. Knight, H. H. 1941. The plant bugs, or Miridae, of Illinois. Bull. Ill. Nat. Hist. Surv. 22 (Artic. 1), 234 p.

676. Knipling, E. F. 1955. Possibilities of insect control or eradication through the use of sexually sterile males. J. Econ. Entomol. 48(4):459-462.

677. Knipling, E. F. 1959. Screwworm eradication: concepts and research leading to the sterile-male method. Smithson. Inst. Annu. Rep. 1958, p. 409-418.

678. Knipling, E. F. 1959. Sterile-male method of population control: successful with some insects, the method may also be effective when applied to other noxious animals. Science 130(3380):902-904.

679. Knipling, E. F. 1960. Use of insects for their own destruction. J. Econ. Entomol. 53(3):415-420.

680. Knipling, E. F. 1963. A new era in pest control: the sterility principle. U.S. Dep. Agric., Agric. Sci. Rev. 1(1):2-12.

681. Knipscher, R. C., D. R. Miller, and J. A. Davidson. 1976. Biosystematics of *Chionaspis nyssae* Comstock (Homoptera: Diaspididae), with evidence supporting leaf and bark dimorphism of the scale. Melanderia 25:1-30.

682. Knull, J. N. 1946. The long-horned beetles of Ohio (Coleoptera: Cerambycidae). Ohio State Univ. Stud., Ohio Biol. Surv. Bull. 39, 7(4):133-354.

683. Knull, J. N. 1951. The checkered beetles of Ohio (Coleoptera: Cleridae). Ohio State Univ. Stud., Ohio Biol. Surv. Bull. 42, 8(2):269-350.

684. Knutson, H. 1944. Minnesota

Phalaenidae (Noctuidae). Univ. Minn. Agric. Exp. Stn., Tech. Bull. 165, 128 p.

685. Koerber, T. W. 1963. *Leptoglossus occidentalis* (Hemiptera: Coreidae), a newly discovered pest of coniferous seed. Ann. Entomol. Soc. Am. 56(2):229-234.

686. Kofoid, C. A., ed. 1934. Termites and termite control. 2d ed., rev. 795 p. Univ. Calif. Press, Berkeley.

687. Kolomiets, N. G., G. V. Stadnitskii, and A. I. Vorontsov. 1979. The European pine sawfly. [Acad. Sci., Siberian Branch, Inst. Biol., 1972.] Transl. from Russian for U.S. Dep. Agric. For. Serv. and Natl. Sci. Found., Washington, D.C. Amerind Publ. Co., New Delhi, TT75-52005, 138 p.

688. Kondo, E. S., Y. Hiratsuka, and W. B. G. Denyer, eds. 1982. Proceedings of the Dutch elm disease symposium and workshop. 517 p. Manitoba Dep. Nat. Resour., Winnipeg.

689. Kosztarab, M. 1963. The armored scale insects of Ohio (Homoptera: Coccoidea: Diaspididae). Bull. Ohio Biol. Surv. (n.s.) 11(2):1-120.

690. Kosztarab, M., and D. F. Vest. 1966. Two new *Cerococcus* species, with a revised key to the genus in North America (Homoptera: Coccoidea: Asterolecaniidae). Ann. Entomol. Soc. Am. 59(2): 369-376.

691. Kotinsky, J. 1921. Insects injurious to deciduous shade trees and their control. U.S. Dep. Agric., Farmers' Bull. 1169, 100 p.

692. Kowal, R. J. 1966. Southern pine beetle. U.S. Dep. Agric. For. Serv., For. Pest Leafl. 49 rev., 8 p.

693. Kraft, K. J. 1968. Ecology of the cone moth *Laspeyresia toreuta*, in *Pinus banksiana* stands. Ann. Entomol. Soc. Am. 61(6):1462-1465.

694. Krauss, N. L. H. 1937. A study of the genus *Glyptoscelis* LeConte in America north of Mexico (Coleoptera: Chrysomelidae). Univ. Calif. Publ. Entomol. 7(2):20-32.

695. Krishna, K., and F. M. Weesner. 1967. Biology of termites. vol. 1. 598 p. Academic Press, New York and London.

696. Kirshna, K., and F. M. Weesner. 1970. Biology of termites. vol. 2. 643 p. Academic Press, New York and London.

697. Krombein, K. V., P. D. Hurd, Jr., D. R. Smith, B. D. Burks, and others. 1979. Catalog of Hymenoptera in America north of Mexico. Vols. 1-3, 2735 p. Smithsonian Institution Press, Washington, D.C.

698. Kucera, D. R., and P. W. Orr. 1981. Spruce budworm in the eastern United States. U.S. Dep. Agric. For. Serv., For. Insect & Dis. Leafl. 160, 7 p.

699. Kulman, H. M. 1965. Natural control of the bagworm and notes on its status as a forest pest. J. Econ. Entomol. 58(5):863-866.

700. Kulman, H. M. 1965. Natural control of the eastern tent caterpillar and notes on its status as a forest pest. J. Econ. Entomol. 58(1):66-70.

701. Kulman, H. M. 1967. Biology of the hard maple bud miner, *Obrussa ochrefasciella*, and notes on its damage (Lepidoptera: Nepticulidae). Ann. Entomol. Soc. Am. 60(2):387-391.

702. Kulman, H. M. 1971. Effects of insect defoliation on growth and mortality of trees. Annu. Rev. Entomol. 16:289-324.

703. Kulman, H. M., and C. K. Dorsey. 1962. Granular application of systemics for control of European pine shoot moth. J. Econ. Entomol. 55(3):304-305.

704. Kulman, H. M., L. C. Thompson, and J. A. Witter.

1974. Introduction of parasites of the larch sawfly in Minnesota. Great Lakes Entomol. 7:23-25.

705. Kulp, L. A. 1968. The taxonomic status of dipterous leafminers (Diptera: Agromyzidae). Univ. Md. Agric. Exp. Stn. Bull. A-155, 42 p. College Park, Md.

706. Kushmaul, R. J., M. D. Cain, C. E. Rowell, and R. L. Porterfield. 1979. Stand and site conditions related to southern pine beetle susceptibility. For. Sci. 25:656-664.

707. LaBonte, G. A. 1978. The saddled prominent outbreak of 1970-71 and its damages. Maine Dep. Conserv., Entomol. Div., Tech. Rep. 1, 20 p. Augusta.

708. Ladd, T. L., Jr., M. Jacobson, and C. R. Buriff. 1978. Japanese beetles: extracts from neem tree seed as feeding deterrents. J. Econ. Entomol. 71:810-813.

709. Ladd, T. L., Jr., and P. J. McCabe. 1967. Persistence of spores of *Bacillus popilliae*, the causal organism of Type A milky disease of Japanese beetle larvae in New Jersey soil. J. Econ. Entomol. 60:493-495.

710. LaFage, J. P., and L. H. Williams. 1979. Lyctid beetles. Recognition, prevention, control. Agric. Exp. Stn. and LSU Circ. 106. 12 p. Baton Rouge, La.

711. Lambdin, P. L., Jr., and M. Kosztarab. 1977. Morphology and systematics of the adult females of the genus *Cerococcus*. Va. Polytech. Inst. & State Univ., Res. Div. Bull. 128:1-252.

712. Langford, G. S. 1926. The life history of the willow scale *(Chionaspis salicis-nigrae* [sic] Walsh). *In* State entomologist of Colorado, seventeenth annual report for 1925. C. P. Gillette, author. State Entomol. Colo. Circ. 51, p. 50-58.

713. Langford, G. S., and H. S. McConnell. 1935. Biology of *Tomostethus multicinctus* (Roh.), a sawfly attacking ash. J. Econ. Entomol. 28(1):208-210.

714. Langlois, T. H., and M. H. Langlois. 1964. Notes on the life-history of the hackberry butterfly, *Asterocampa celtis* (Bdvl. & Lec.) on South Bass Island, Lake Erie: (Lepidoptera: Nymphalidae). Ohio J. Sci. 64(1):1-11.

715. Lanier, G. N. 1978. Vectors. *In* The Dutch elm disease: prospective after 60 years. p. 13-17. W. A. Sinclair and R. J. Campana, eds. Search (Agric.) 8(5):1-52.

716. Lanier, G. N. 1981. Pheromone baited traps and trap trees in the integrated management of bark beetles in urban areas. *In* Management of insect pests with semiochemicals. p. 115-131. E. R. Mitchell, ed. Plenum Publ. Corp., New York.

717. Lanier, G. N. 1982. Dutch elm disease: a postscript. Arnoldia 42:78-87.

718. Lanier, G. N., and A. H. Epstein. 1978. Vector suppression. *In* The Dutch elm disease: prospective after 60 years. p. 30-32. W. A. Sinclair and R. J. Campana, eds. Search (Agric.) 8(5):1-52.

719. Leach, J. G., L. W. Orr, and C. Christensen. 1937. Further studies on the interrelationship of insects and fungi in the deterioration of felled Norway pine logs. J. Agric. Res. 55(2):129-140.

720. Lee, K. E., and T. G. Wood. 1971. Termites and soils. 251 p. Academic Press, New York and London.

721. Lelláková-Dušková, F. 1963. The morphology, metamorphosis, and life-cycle of the scale insect *Quadraspidiotus gigas* (Thiem et Gerneck) (Homoptera: Coccoidea: Diaspididae). Acta Entomol. Mus.

Natl. Pragae 35:611-648.
722. Lelláková-Dušková, F. 1966. Die auf weidengewächsen (Salicales) lebenden Schildläuse *(Coccoidea)* in der Tschechoslowakei. Z. Angew. Entomol. 57(3):294-309.
723. Leng, C. W. 1920. Catalogue of the Coleoptera of America, north of Mexico. 470 p. John D. Sherman, Jr., Mount Vernon, N.Y.
724. Leng, C. W., and A. J. Mutchler. 1927. Supplement: 1919 to 1924 (inclusive) to catalogue of the Coleoptera of America, north of Mexico. 78 p. John D. Sherman, Jr., Mount Vernon, N.Y.
725. Leng, C. W., and A. J. Mutchler. 1933. Second and third supplements: 1925 to 1932 (inclusive) to catalogue of the Coleoptera of America, north of Mexico. 112 p. John D. Sherman, Jr., Mount Vernon, N.Y.
726. Leonard, D. E. 1974. Recent developments in ecology and control of the gypsy moth. Annu. Rev. Entomol. 19: 197-229.
727. Leonard, D. E. 1981. Bioecology of the gypsy moth. *In* The gypsy moth: research toward integrated pest management. C. C. Doane and M. L. McManus, eds. U.S. Dep. Agric. For. Serv., Sci. and Educ. Agency, and Anim. and Plant Health Insp. Serv. Tech. Bull. 1584, p. 9-29.
728. Leonard, M. D., editor-in-chief. 1928. A list of the insects of New York: with a list of the spiders and certain other allied groups. Cornell Univ. Agric. Exp. Stn. Memo. 101, 1121 p.
729. Levy, M. P. [1979.] A guide to the inspection of existing homes for wood-inhabiting fungi and insects. 104 p. U.S. Dep. Housing and Urban Dev., Washington, D.C.
730. Levy, M. P. [1979.] A guide to the inspection of new houses under construction for conditions which favor attack by wood-inhabiting fungi and insects. 42 p. U.S. Dep. Housing and Urban Dev., Washington, D.C.
731. Lewis, F. B. 1981. Gypsy moth nucleopolyhedrosis virus. *In* The gypsy moth: research toward integrated pest management. C. C. Doane and M. L. McManus, eds. U.S. Dep. Agric. For. Serv., Sci. and Educ. Agency, and Anim. and Plant Health Insp. Serv. Tech. Bull. 1584, p. 454-455.
732. Lewis, F. B., M. L. McManus, and N. F. Schneeberger. 1979. Guidelines for the use of GYPCHEK to control the gypsy moth. U.S. Dep. Agric. For. Serv., Res. Pap. NE-441, 9 p. Northeast. For. Exp. Stn., Broomall, Pa.
733. Lewis, F. B., and W. G. Yendol. 1981. Efficacy. *In* The gypsy moth: research toward integrated pest management. C. C. Doane and M. L. McManus, eds. U.S. Dep. Agric. For. Serv., Sci. and Educ. Agency, and Anim. and Plant Health Insp. Serv. Tech. Bull. 1584, p. 503-512.
734. Lindquist, A. W. 1955. The use of gamma radiation for control or eradication of the screwworm. J. Econ. Entomol. 48(4):467-469.
735. Lindquist, A. W. 1960. Use of sexually sterile males for eradication of screw-worms. *In* 2d Inter-American symposium on the peaceful application of nuclear energy, Buenos Aires, 1959, p. 229-235.
736. Lindquist, O. H., and R. L. Bowser. 1966. A biological study of the leaf miner, *Chrysopeleia ostryaella* Chambers (Lepidoptera: Cosmopterygidae), on ironwood in Ontario. Can. Entomol. 98(3): 252-258.
737. Lindquist, O. H., and G. G.

Jackson. 1965. A leaf-mining sawfly on oak. Can. Dep. For. Bimon. Prog. Rep. 21(4):1-4.

738. Lindquist, O. H., and P. D. Syme. 1981. Insects and mites associated with Ontario forests: classification, common names, main hosts, and importance. Can. For. Serv., Great Lakes For. Res. Cent. Inf. Rep. O-X-333, 116 p. Sault Ste. Marie, Ontario.

739. Lindquist, O. H., and J. R. Trinnell. 1967. The biology and description of immature stages of *Exoteleia nepheos* (Gelechiidae) on pine in Ontario. J. Lepid. Soc. 21(1):15-21.

740. Linscott, D. 1963. The susceptibility of timber to attack and the probability of an infestation by *Anobium punctatum* (Deg.). *In* Record of the 1963 annual convention of the British Wood Preserving Association, Cambridge, July 8-11, 1963, p. 49-92. [Issued by Br. Wood Preserv. Assoc., London.]

741. Linsley, E. G. 1940. Notes on *Oncideres* twig girdlers. J. Econ. Entomol. 33(3):561-563.

742. Linsley, E. G. 1961. The Cerambycidae of North America. Part I. Introduction. Univ. Calif. Publ. Entomol. 18:1-135.

743. Linsley, E. G. 1962. The Cerambycidae of North America. Part II. Taxonomy and classification of the Parandrinae, Prioninae, Spondylinae, and Aseminae. Univ. Calif. Publ. Entomol. 19:1-102.

744. Linsley, E. G. 1962. The Cerambycidae of North America. Part III. Taxonomy and classification of the subfamily Cerambycinae, tribes Opsimini through Megaderini. Univ. Calif. Publ. Entomol. 20:1-188.

745. Linsley, E. G. 1963. The Cerambycidae of North America. Part IV. Taxonomy and classification of the subfamily Cerambycinae, tribes Elaphidionini through Rhinotragini. Univ. Calif. Publ. Entomol. 21:1-165.

746. Linsley, E. G. 1964. The Cerambycidae of North America. Part V. Taxonomy and classification of the subfamily Cerambycinae, tribes Callichromini through Ancylocerini. Univ. Calif. Publ. Entomol. 22:1-197.

747. Linsley, E. G., and J. A. Chemsak. 1972. Cerambycidae of North America. Part VI, No. 1. Taxonomy and classification of the subfamily Lepturinae. Univ. Calif. Publ. Entomol. 69:1-138.

748. Linsley, E. G., and J. A. Chemsak. 1976. Cerambycidae of North America. Part VI, No. 2. Taxonomy and classification of the subfamily Lepturinae. Univ. Calif. Publ. Entomol. 80:1-186.

749. Lofgren, C. S., W. A. Banks, and B. M. Glancey. 1975. Biology and control of imported fire ants. Annu. Rev. Entomol. 20:1-30.

750. Loomis, R. C., and T. H. Hofacker. 1981. Forest insect and disease conditions in the United States 1980. 36 p. U.S. Dep. Agric. For. Serv., For. Pest Manage., Washington, D.C.

751. Lorio, P. L., G. N. Mason, and G. L. Autry. 1982. Stand risk rating for the southern pine beetle: integrating pest management with forest management. J. For. 80:212-214.

752. Lowe, J. H., Jr. 1966. Biology and dispersal of *Pineus pinifoliae* (Fitch). Ph.D. Thesis. Yale Univ., New Haven, Conn. 104 p.

753. Lowe, R. E., R. L. Giese, and M. L. McManus. 1967. Mycetangia of the ambrosia *Monarthrum fasciatum*. J. Invertebr. Pathol. 9(4):451-458.

754. Luck, R. F., and D. L. Dahlsten. 1974. Bionomics of the pine needle scale, *Chionaspis pinifoliae*, and its natural enemies at South Lake Tahoe, Calif. Ann. Entomol.

Soc. Am. 67(3):309-316.

755. Luck, R. F., and D. L. Dahlsten. 1975. Natural decline of a pine needle scale, *Chionaspis pinifoliae* (Fitch), outbreak at South Tahoe Lake, California, following cessation of adult mosquito control with malathion. Ecology 56: 893-904.

756. Luginbill, P., Sr., and H. R. Painter. 1953. May beetles of the United States and Canada. U.S. Dep. Agric., Tech. Bull. 1060, 102 p.

757. Lund, A. E. 1967. The study of subterranean termites: a laboratory and field approach. *In* Record of the 1967 annual convention of the British Wood Preserving Association, Cambridge, June 20-23, 1967, p. 119-127. [Issued by Br. Wood Preserv. Assoc., London.]

758. Lyons, L. A. 1956. Insects affecting seed production in red pine. Part I. *Conophthorus resinosae* Hopk. (Coleoptera: Scolytidae). Can. Entomol. 88(10):599-608.

759. Lyons, L. A. 1957. Insects affecting seed production in red pine. Part II. *Dioryctria disclusa* Heinrich, *D. abietella* (D. and S.), and *D. cambiicola* (Dyar) (Lepidoptera: Phycitidae). Can. Entomol. 89(2):70-79.

760. Lyons, L. A. 1957. Insects affecting seed production in red pine. Part III. *Eucosma monitorana* Heinrich, *Laspeyresia toreuta* Grote (Lepidoptera: Olethreutidae), *Rubsaamenia* sp. (Diptera: Cecidomyiidae), and other insects. Can. Entomol. 89(4):150-164.

761. Lyons, L. A. 1964. The European pine sawfly, *Neodiprion sertifer* (Geoff.) (Hymenoptera: Diprionidae). A review with emphasis on studies in Ontario. Proc. Entomol. Soc. Ont. 94:5-37.

762. MacAloney, H. J. 1930. The white pine weevil (*Pissodes strobi* Peck)—its biology and control. Bull. N.Y. State Coll. For. at Syracuse Univ., Tech. Publ. 28, 87 p.

763. MacAloney, H. J. 1961. Pine tortoise scale. U.S. Dep. Agric. For. Serv., For. Pest Leafl. 57, 7 p.

764. MacAloney, H. J. 1967. The hemlock borer. U.S. Dep. Agric. For. Serv., For. Pest Leafl. 109, 4 p.

765. MacAloney, H. J. 1968. The bronze birch borer. U.S. Dep. Agric. For. Serv., For. Pest Leafl. 111, 4 p.

766. MacAloney, H. J. 1971. The sugar maple borer. U.S. Dep. Agric. For. Serv., For. Pest Leafl. 108 rev. 4 p.

767. MacAloney, H. J., and H. G. Ewan. 1964. Identification of hardwood insects by type of tree injury, North Central region. U.S. Dep. Agric. For. Serv., Lake States For. Exp. Stn. & North Cent. Reg., Res. Pap. LS-11, 70 p. [North Cent. For. Exp. Stn., St. Paul, Minn.]

768. MacAloney, H. J., and D. C. Schmiege. 1962. Identification of conifer insects by type of tree injury, Lake States. U.S. Dep. Agric. For. Serv., Lake States For. Exp. Stn. & North Cent. Reg., Stn. Pap. 100, 42 p. [North Cent. For. Exp. Stn., St. Paul, Minn.]

769. MacAloney, H. J., and L. F. Wilson. 1957. The red-headed pine sawfly. U.S. Dep. Agric. For. Serv., For. Pest Leafl. 14 rev., 5 p.

770. McCambridge, W. F., and G. L. Downing. 1960. Black-headed budworm. U.S. Dep. Agric. For. Serv., For. Pest Leafl. 45, 4 p.

771. McClure, M. S. 1976. Colonization and establishment of the red pine scale, *Matsucoccus resinosae* (Homoptera: Margarodidae) in a Connecticut

plantation. Environ. Entomol. 5(5):943-947.

772. McClure, M. S. 1977. Population dynamics of the red pine scale, *Matsucoccus resinosae* (Homoptera: Margarodidae): the influence of resinosus. Environ. Entomol. 6:789-798.

773. McClure, M. S. 1978. Seasonal development of *Fiorina externa, Tsugaspidiotus tsugae,* and their parasite, *Aspidiotiphagus citrinus:* importance of parasite-host synchronism to the population dynamics of two scale pests of hemlock. Environ. Entomol. 7:863-870.

774. McClure, M. S. 1982. Distribution and damage of two *Pineus* species (Homoptera: Adelgidae) on red pine in New England. Ann. Entomol. Soc. Am. 75:150-157.

775. McClure, M. S., and M. B. Fergione. 1977. *Fiorina externa* and *Tsugaspidiotus tsugae:* distribution, abundance, and new hosts of two destructive scale insects of eastern hemlock in Connecticut. Environ. Entomol. 6:807-811.

776. McConnell, H. S., and J. A. Davidson. 1959. Observations on the life history and morphology of *Kermes pubescens* Bogue (Homoptera: Coccoidea: Dactylopiidae). Ann. Entomol. Soc. Am. 52(4):463-468.

777. MacCreary, D. 1945. Ticks of Delaware: with special reference to *Dermacentor variabilis* (Say) vector of Rocky Mountain spotted fever. Univ. Del. Agric. Exp. Stn. Bull. 252 (Tech. 32), 22 p.

778. MacDonald, J. F., R. D. Akre, and R. W. Matthews. 1976. Evaluation of yellowjacket abatement in the United States. Bull. Entomol. Soc. Am. 22(4):397-401.

779. MacDonald, J. F., and R. W. Matthews. 1975. *Vespula squamosa:* a yellow jacket wasp evolving toward parasitism. Science 190(4218):1003-1004.

780. McGraw, J. R., and M. H. Farrier. 1969. Mites of the superfamily Parasitoidea (Acarina: Mesostigmata) associated with *Dendroctonus* and *Ips* (Coleoptera: Scolytidae). N.C. Agric. Exp. Stn. Tech. Bull. 192, 162 p. Raleigh, N.C.

781. McGregor, E. A. 1950. Mites of the family Tetranychidae. Am. Midl. Nat. 44(2):257-420.

782. McGuffin, W. C. 1972. Guide to the Geometridae of Canada (Lepidoptera). Part II. Subfamily Ennominae. Volume 1. Mem. Entomol. Soc. Can. 86, 159 p.

783. McGuffin, W. C. 1977. Guide to the Geometridae of Canada (Lepidoptera). Part II. Subfamily Ennominae. Volume 2. Mem. Entomol. Soc. Can. 101, 191 p.

784. McGuffin, W. C. 1981. Guide to the Geometridae of Canada (Lepidoptera). II. Subfamily Ennominae. 3. Mem. Entomol. Soc. Can. 117, 153 p.

785. McGugan, B. M., compiler. 1958. Forest Lepidoptera of Canada. Recorded by the forest insect survey. vol 1. Papilionidae to Arctiidae. Can. Dep. Agric., Dep. Agric. Publ. 1034, 76 p.

786. McGugan, B. M. 1958. The Canadian forest insect survey. Proc. 10th Int. Congr. Entomol., vol. 4, p. 219-232. [Montreal, Aug. 17-25, 1956.]

787. McGugan, B. M., and J. R. Blais. 1959. Spruce budworm parasite studies in northwestern Ontario. Can. Entomol. 91(12):758-783.

788. McGugan, B. M., and H. C. Coppel. 1962. Part II—Biological control of forest insects, 1910-1958. *In* A review of the biological control attempts against insects and weeds in Canada. Commonw. Inst. Biol.

Control, Tech. Commun. 2, p. 35-216. [Commonw. Agric. Bur., Farnham Royal, Bucks, England.]

789. McIntyre, T. 1960. Natural factors control the pine tortoise scale in the Northeast. J. Econ. Entomol. 53(2):325.

790. McIntyre, T., and S. R. Dutky. 1961. Aerial application of virus for control of a pine sawfly, *Neodiprion pratti pratti*. J. Econ. Entomol. 54(4):809-810.

791. MacKay, M. R. 1943. The spruce foliage worm and the spruce cone worm *(Dioryctria* spp., Lepidoptera, Pyralidae). Can. Entomol. 75(5):91-98.

792. MacKay, M. R. 1959. Larvae of the North American Olethreutidae (Lepidoptera). Can. Entomol. Suppl. 10, 338 p.

793. MacKay, M. R. 1962. Additional larvae of the North American Olethreutinae (1) (Lepidoptera: Tortricidae). Can. Entomol. 94(6):626-643.

794. MacKay, M. R. 1962. Larvae of the North American Tortricinae (Lepidoptera: Tortricidae). Can. Entomol. Suppl. 28, 182 p.

795. MacKay, M. R. 1968. The North American Aegeriidae (Lepidoptera): a revision based on late-instar larvae. Mem. Entomol. Soc. Can. 58, 112 p.

796. McKenzie, H. L. 1967. Mealybugs of California. 525 p. Calif. Univ. Press, Berkeley.

797. McKnight, M. E. 1968. A literature review of the spruce, western, and 2-year-cycle budworms. U.S. Dep. Agric. For. Serv., Res. Pap. RM-44, 35 p. Rocky Mt. For. & Range Exp. Stn., Fort Collins, Colo.

798. McKnight, M. E. 1973. Parasitoids reared from collections of *Rhyacionia bushnelli* from the Great Plains (Lepidoptera: Olethreutidae). J. Kans. Entomol. Soc. 46:139-143.

799. McLean, D. A. 1980. Vulnerability of fir-spruce stands during uncontrolled spruce budworm outbreaks: a review and discussion. For. Chron. 56:213-221.

800. MacLean, D. B., and R. L. Giese. 1967. The life history of the ambrosia beetle *Xyloterinus politus* (Coleoptera: Scolytidae). Can. Entomol. 99(3):285-299.

801. MacLean, D. B., and R. L. Giese. 1968. Fungi associated with *Xyloterinus politus* (Say) (Coleoptera: Scolytidae). J. Invertebr. Pathol. 10(2):185-189.

802. McLeod, J. M. 1966. Notes on the biology of a spruce needleminer, *Pulicalvaria piceaella* (Kearfott) (Lepidoptera: Gelechiidae). Can. Entomol. 98(3):225-236.

803. McLeod, J. M. 1970. The epidemiology of the Swaine jack pine sawfly, *Neodiprion swainei* Midd. For. Chron. 46:126-133.

804. McLeod, J. M. 1979. Discontinuous stability in a sawfly life system and its relevance to pest management strategies. *In* Current topics in forest entomology: selected papers from the 15th International Congress of Entomology. W.E. Waters, ed. U.S. Dep. Agric. For. Serv., Gen. Tech. Rep. WO-8, p. 68-81. Washington, D.C.

805. McLeod, J. M., and L. Daviault. 1963. Notes on the life history and habits of the spruce cone worm, *Dioryctria reniculella* (Grt.) (Lepidoptera: Pyralidae). Can. Entomol. 95(3):309-316.

806. McLintock, T. F. 1947. Silvicultural practices for control of spruce budworm. J. For. 45(9):655-658.

807. McLintock, T. F. 1948. Evaluation of tree risk in the spruce-fir region of the Northeast. Iowa State Coll. J. Sci. 22(4): 415-419.

808. McLintock, T. F. 1949. Mapping vulnerability of spruce-fir stands in the Northeast to spruce

budworm attack. U.S. Dep. Agric. For. Serv., Stn. Pap. 21, 20 p. Northeast. For. Exp. Stn., Broomall, Pa.

809. McManus, M. L., and R. L. Giese. 1968. The Columbian timber beetle, *Corthylus columbianus*. Part VII. The effect of climatic integrants on historic density fluctuations. For. Sci. 14(3):242-253.

810. McManus, M. L., and T. McIntyre. 1981. Introduction. *In* The gypsy moth: research toward integrated pest management. C. C. Doane and M. L. McManus, eds. U.S. Dep. Agric. For. Serv., Sci. and Educ. Agency, and Anim. and Plant Health Insp. Serv. Tech. Bull. 1584, p. 1-7.

811. McMullen, L. H., C. R. Drake, R. D. Shenefelt, and J. E. Kuntz. 1955. Long distance transmission of oak wilt in Wisconsin. Plant Dis. Rep. 39(1):51-53.

812. Madsen, H. F., and P. H. Westigard. 1962. Behavior and control of the grape mealybug on pear. J. Econ. Entomol. 55(6):849-850.

813. Maier, C. T. 1980. Quince curculio, *Conotrachelus crataegi* Walsh (Coleoptera: Curculionidae), developing in apple, a new host, in southern New England. Proc. Entomol. Soc. Wash. 82:59-62.

814. Marrone, P. G., and D. B. Zepp. 1979. Description of the larva and pupa of *Callirhopalus* (subg. *Pseudoencorhinus) bifasciatus*, the twobanded Japanese weevil, with new host plant records. Ann. Entomol. Soc. Am. 72:833-836.

815. Martignoni, M. E., and P. J. Iwai. 1981. Catalogue of viral diseases of insects, mites, and ticks. *In* Microbial control of pests and plant diseases. p. 897-911. H. D. Burges, ed., Academic Press, New York.

816. Martignoni, M. E., and R. L. Langston. 1960. Supplement to an annotated list and bibliography of insects reported to have virus diseases. Hilgardia 30(1):1-40.

817. Martin, J. L. 1956. The bionomics of the aspen blotch miner, *Lithocolletis salicifoliella* Cham. (Lepidoptera: Gracillariidae). Can. Entomol. 88(4):155-168.

818. Martin, J. L. 1958. Observations on the biology of certain tortricids in young coniferous plantations in southern Ontario. Can. Entomol. 90(1):44-53.

819. Martin, J. L. 1959. The bionomics of the pine bud moth, *Exoteleia dodecella* L. (Lepidoptera: Gelechiidae), in Ontario. Can. Entomol. 91(1): 5-14.

820. Martin, J. L. 1960. Life history of the pine tip moth, *Rhyacionia adana* Heinrich, in Ontario (Lepidoptera: Olethreutidae). Can. Entomol. 92(10):724-728.

821. Martin, J. L. 1960. The bionomics of *Profenusa thomsoni* (Konow) (Hymenoptera: Tenthredinidae) a leaf-mining sawfly on *Betula* spp. Can. Entomol. 92(5):376-384.

822. Martin, J. L. 1964. The insect ecology of red pine plantations in central Ontario. Part II. Life history and control of Curculionidae. Can. Entomol. 96(11):1408-1417.

823. Marty, R., and D. G. Mott. 1964. Evaluating and scheduling white-pine weevil control in the Northeast. U.S. Dep. Agric. For. Serv., Res. Pap. NE-19, 56 p. Northeast. For. Exp. Stn., Broomall, Pa.

824. Mason, C. J., and M. L. McManus. 1981. Larval dispersal of the gypsy moth. *In* The gypsy moth: research toward integrated pest management. C. C. Doane and M. L. McManus, eds. U.S. Dep.

Agric. For. Serv., Sci. and Educ. Agency, and Anim. and Plant Health Insp. Serv. Tech. Bull. 1584, p. 161-202.

825. Mason, W. R. M. 1981. The polyphyletic nature of *Apanteles* Foerster (Hymenoptera: Braconidae): a phylogeny and reclassification of Microgastrinae. Mem. Entomol. Soc. Can. 115, 147 p.

826. Massey, C. L. 1966. The influence of nematode parasites and associates on bark beetles in the United States. Bull. Entomol. Soc. Am. 12(4):384-386.

827. Mastro, V. C., C. P. Schwalbe, and T. M. ODell. 1981. Sterile-male technique. *In* The gypsy moth: research toward integrated pest management. C. C. Doane and M. L. McManus, eds. U.S. Dep. Agric. For. Serv., Sci. and Educ. Agency, and Anim. and Plant Health Insp. Serv. Tech. Bull. 1584, p. 669-679.

828. Matheson, R. 1951. Entomology for introductory courses. 2d ed. 629 p. Comstock Publ. Assoc., Ithaca, N.Y.

829. Matsuo, H., and K. Nishimoto. 1974. Response of the termite *Coptotermes formosanus* (Shiraki) to extract fractions from fungus-infected wood and fungus mycelium. Mater. und Org. 9(3):225-238.

830. Mattoon, W. R. 1937. Growing black locust trees. U.S. Dep. Agric., Farmers' Bull. 1628 rev., 30 p.

831. Mattson, W. J., and N. D. Addy. 1975. Phytophagous insects as regulators of forest primary production. Science 190:515-522.

832. Mauldin, J. K. 1982. The economic importance of termites in North America. *In* The biology of social insects. p.138-141. M. D. Breed, C. D. Michener, H. E. Evans, eds. Proc. Ninth Congr. Int. Union for the Study of Social Insects. Westview Press, Boulder, Colo.

833. Mauldin, J. K., E. N. Lambremont, and J. B. Graves. 1971. Principal lipid classes and fatty acids synthesized during growth and development of the beetle *Lyctus planicollis*. Insect Biochem. 1(3):316-326.

834. Mayet, V. 1906. Longévité des *Margarodes*. Bull. Soc. Entomol. Fr., 11:228-229.

835. Maynard, E. A. 1951. A monograph of the Collembola or springtail insects of New York State. 339 p. Comstock Publ. Co., Inc., Ithaca, N.Y.

836. Merkel, E. P. 1967. Life history of the slash pine seedworm, *Laspeyresia anaranjada* Miller (Lepidoptera: Olethreutidae). Fla. Entomol. 50(3):141-149.

837. Merkel, E. P. 1969. Control of insects in slash pine cones with trunk implantations of Bidrin® systemic insecticide—first-year results. U.S. Dep. Agric. For. Serv., Res. Note SE-109, 4 p. Southeast. For. Exp. Stn., Asheville, N.C.

838. Merkel, E. P. 1969. Insect control in forest tree seed orchards. J. For. 67:748-750.

839. Merkel, E. P. 1982. Biology of the baldcypress coneworm, *Dioryctria pygmaeella* Ragonot (Lepidoptera: Pyralidae), in north Florida. J. Ga. Entomol. Soc. 17:13-19.

840. Metcalf, C. L. 1913. The Syrphidae of Ohio. Ohio Biol. Surv. Bull. 1:1-122, [Also issued as Ohio State Univ. Bull., vol. 17(31).]

841. Metcalf, Z. P. 1922. The gloomy scale. N.C. Agric. Exp. Stn., Tech. Bull. 21, 23 p.

842. Metz, L. J., and D. L. Dindal. 1975. Collembola populations and prescribed burning. Environ. Entomol. 4:583-587.

843. Metz, L. J., and M. H. Farrier. 1973. Prescribed burning and populations of soil mesofauna. Environ. Entomol. 2:433-440.

844. Mickel, C. E. 1928. Biological and taxonomic investigations on the mutillid wasps. U.S. Natl. Mus. Bull. 143, 351 p.
845. Middlekauff, W. W. 1958. The North American sawflies of the genera *Acantholyda, Cephalcia,* and *Neurotoma* (Hymenoptera, Pamphiliidae). Univ. Calif. Publ. Entomol. 14(2):51-174.
846. Middleton, W. 1923. The imported pine sawfly. U.S. Dep. Agric. Bull. 1182, 22 p.
847. Mielke, M. E., C. Haynes, and W. L. MacDonald. 1982. Beech scale and *Nectria galligena* on beech in the Monongahela National Forest, West Virginia. Plant Dis. 66:851-852.
848. Miller, C. A. 1963. Parasites and the spruce budworm. Mem. Entomol. Soc. Can. 31: 228-244.
849. Miller, J. M. 1950. Resistance of pine hybrids to the pine reproduction weevil. U.S. Dep. Agric. For. Serv., For. Res. Notes 68, 17 p. Calif. For. & Range Exp. Stn., Berkeley, Calif.
850. Miller, W. E. 1955. Biology of *Anacampsis innocuella* (Zeller), a leafroller on aspen. J. Econ. Entomol. 48(5):622-623.
851. Miller, W. E. 1963. The shortleaf pitch-blister moth, *Petrova houseri* Miller. Ohio J. Sci. 63(6):297-301.
852. Miller, W. E. 1965. Protecting Christmas tree plantations. J. For. 63(11):849-852.
853. Miller, W. E. 1967. The European pine shoot moth—ecology and control in the Lake States. For. Sci. Monogr. 14, 72 p.
854. Miller, W. E. 1978. *Petrova* pitch-blister moths of North America and Europe: two new species and synopsis (Olethreutidae). Ann. Entomol. Soc. Am. 71(3):329-340.
855. Miller, W. E. 1978. Use of prescribed burning in seed production areas to control red pine cone beetle. Environ. Entomol. 7:698-702.
856. Miller, W. E., A. R. Hastings, and V. M. Carolin. 1970. European pine shoot moth. U.S. Dep. Agric. For. Serv., For. Pest Leafl. 59 rev., 8 p.
857. Miller, W. E., K. J. Kessler, Jr., J. H. Ohman, and J. T. Eschle. 1978. Timber quality of northern hardwood regrowth in the Lake States. For. Sci. 24:247-259.
858. Miller, W. E., and R. B. Neiswander. 1955. Biology and control of the European pine shoot moth. Ohio Agric. Exp. Stn., Res. Bull. 760, 31 p.
859. Miller, W. E., and R. B. Neiswander. 1956. The pitch twig moth and its occurrence in Ohio. Ohio Agric. Exp. Stn., Res. Bull. 779, 24 p.
860. Miller, W. E., R. F. Wambach, and R. A. Anfang. 1978. Effect of past European pine shoot moth infestations on volume yield of pole-sized red pine. For. Sci. 24:543-550.
861. Millers, I., D. M. Benjamin, and R. E. Warner. 1963. A new *Hylobius* weevil associated with jack pine stand deterioration (Coleoptera: Curculionidae). Can. Entomol. 95(1):18-22.
862. Mills, H. B. 1934. A monograph of the Collembola of Iowa. 143 p. Collegiate Press, Inc., Ames, Iowa.
863. Milstead, J. E., M. Kirby, D. Pinnock, N. Farmer, B. Nelson, D. Odom, and T. Rozek. 1980. Evaluation of commercial formulations of *Bacillus thuringiensis* Berliner for the control of tent caterpillars infesting oaks. FAO Plant Prot. Bull. 28:72-74.
864. Mitchell, R. T. 1952. Consumption of spruce budworms by birds in a Maine spruce-fir forest. J. For. 50(5):387-389.
865. Mitchell, R. T., and H. S. Zim. 1964. Butterflies and moths; a

guide to the more common American species. 160 p. Golden Press, New York.

866. Mitter, C., and D. Futuyma. 1977. Parthenogenesis in the fall cankerworm, *Alsophila pometaria* (Lepidoptera, Geometridae). Entomol. Exp. & Appl. 21:192-198.

867. Moore, G. E. 1971. Mortality factors caused by pathogenic bacteria and fungi of the southern pine beetle in North Carolina. J. Invert. Pathol. 17:28-37.

868. Moore, G. E. 1972. Southern pine beetle mortality in North Carolina caused by parasites and predators. Environ. Entomol. 1:58-65.

869. Moore, H. B. 1968. Development and longevity of *Xyletinus pelatatus* under constant temperatures and humidities. Ann. Entomol. Soc. Am. 61(5): 1158-1164.

870. Moore, H. B. 1978. The old house borer: an update. Pest Control 46(3):14-17, 52-53; (4):28,30,32; (5):26-28.

871. Moore, H. B. 1979. Wood-inhabiting insects in houses: their identification, biology, prevention and control. 133 p. U.S. Dep. Agric. For. Serv. and Dep. Housing and Urban Dev., Washington, D.C.

872. Morris, C. L., W. J. Schroeder, and M. L. Bobb. 1963. A pine sawfly *Neodiprion pratti pratti* in Virginia. 42 p. Va. Div. For., Dep. Conserv. & Econ. Dev.

873. Morris, O. N. 1980. Entomopathogenic viruses: strategies for use in forest insect pest management. Can. Entomol. 112:573-584.

874. Morris, R. C. 1960. Control of cottonwood insects with a systemic insecticide. J. For. 58(9):718.

875. Morris, R. C. 1963. Trunk borers in cottonwood. Miss. Agric. Exp. Stn., Inf. Sheet 826, 2 p.

876. Morris, R. C. 1964. "Grease-spot" in oak—blemish or beauty? South. Lumberman 208(2592):23, 26.

877. Morris, R. C. 1967. Biology of *Gypsonoma haimbachiana* (Lepidoptera: Olethreutidae), a twig borer in eastern cottonwood. Ann. Entomol. Soc. Am. 60(2):423-427.

878. Morris, R. C., T. H. Filer, J. D. Solomon, F. I. McCracken, N. A. Overgaard, and M. J. Weiss. 1975. Insects and diseases of cottonwood. U.S. Dep. Agric., For. Serv. Gen. Tech. Rep. SO-8, 37 p. South. For. Exp. Stn., New Orleans, La.

879. Morris, R. F. 1951. The larval Elateridae of eastern spruce forests and their role in the natural control of *Gilpinia hercyniae* (Htg.) (Hymenoptera: Diprionidae). Can. Entomol. 83(6):133-147.

880. Morris, R. F. 1955. The development of sampling techniques for forest insect defoliators, with particular reference to the spruce budworm. Can. J. Zool. 33(4):225-294.

881. Morris, R. F. 1963. Synonymy and color variation in the fall webworm, *Hyphantria cunea* Drury (Lepidoptera: Arctiidae). Can. Entomol. 95:1217-1223.

882. Morris, R. F., ed. 1963. The dynamics of epidemic spruce budworm populations. Mem. Can. Entomol. Soc. 31, 332 p.

883. Morris, R. F. 1971. The influence of land use and vegetation on the population density of *Hyphantria cunea*. Can. Entomol. 103(11):1525-1536.

884. Morris, R. F. 1972. Fecundity and colony size in natural populations of *Hyphantria cunea*. Can. Entomol. 104(3):399-409.

885. Morris, R. F. 1980. Notes on the occurrence of the wharf borer *Nacerdes melanura* (Coleoptera: Oedemeridae) in Newfoundland. Can. Entomol. 112:217-218.

886. Morrison, H. 1925. Classification of scale insects of the subfamily Ortheziinae. J. Agric. Res. 30(2):97-154.

887. Morrison, H. 1928. A classification of the higher groups and genera of the coccid family Margarodidae. U.S. Dep. Agric., Tech. Bull. 52, 240 p.

888. Morrison, H. 1952. Classification of the Ortheziidae: supplement to classification of scale insects of the subfamily Ortheziinae. U.S. Dep. Agric., Tech. Bull. 1052, 80 p.

889. Morse, A. P. 1920. Manual of the Orthoptera of New England, including the locusts, grasshoppers, crickets, and their allies. Boston Soc. Nat. Hist. 35(6): 203-556.

890. Moser, J. C. 1965. The interrelationships of three gall makers and their natural enemies, on hackberry *(Celtis occidentalis* L.). N.Y. State Mus. & Sci. Ser. Bull. 402, 95 p.

891. Moser, J. C., and L. M. Roton. 1971. Mites associated with southern pine bark beetles in Allen Parish, Louisiana. Can. Entomol. 103(12):1775-1798.

892. Mosher, D. G., and L. F. Wilson. 1975. Life history and some habits of a larch moth, *Paralobesia palliolana* (Lepidoptera: Tortricidae), in Michigan. Great Lakes Entomol. 7(4):133-136.

893. Mosher, F. H. 1915. Food plants of the gipsy moth in America. U.S. Dep. Agric. Bull. 250, 39 p.

894. Muesebeck, C. F. W. 1918. Two important introduced parasites of the brown-tail moth. J. Agric. Res. 14(5):191-206.

895. Muesebeck, C. F. W. 1978. A new egg parasite (Hymenoptera: Scelionidae) of the elm spanworm, *Ennomos subsignarius* (Lepidoptera: Geometridae). Proc. Entomol. Soc. Wash. 80(1):91-93.

896. Muldrew, J. A. 1967. Biology and initial dispersal of *Olesicampe (Holocremnus)* sp. nr. *nematorum* (Hymenoptera: Ichneumonidae), a parasite of the larch sawfly recently established in Manitoba. Can. Entomol. 99(3):312-321.

897. Munroe, E. 1959. Canadian species of *Dioryctria* Zeller (Lepidoptera: Pyralidae). Can. Entomol. 91(2):65-72.

898. Murakami, Y. 1970. A review of biology and ecology of diaspine scales in Japan: (Homoptera, Coccoidea). Mushi 43(7):65-114.

899. Mutuura, A. 1982. American species of *Dioryctria* (Lepidoptera: Pyralidae). VI. A new species of *Dioyryctria* from eastern Canada and northeastern United States. Can. Entomol. 114: 1069-1076.

900. Mutuura, A., and T. N. Freeman. 1966. The North American species of the genus *Zeiraphera* Treitschke (Olethreutidae). J. Res. Lepid. 5(3):153-176.

901. Mutuura, A., and E. Munroe. 1973. American species of *Dioryctria* (Lepidoptera: Pyralidae). IV. The *schuetzeela* group and the taxonomic status of the spruce cone moth. Can. Entomol. 105(4):653-668.

902. Mutuura, A., and E. Munroe. 1979. American species of *Dioryctria* (Lepidoptera: Pyralidae). V. Three new cone-feeding species from the southeastern United States. J. Ga. Entomol. Soc. 14:290-304.

903. Nagel, R. H., D. McComb, and F. B. Knight. 1957. Trap tree method for controlling the Engelmann spruce beetle in Colorado. J. For. 55(12):894-898.

904. Nakahara, S. 1982. Checklist of the armored scales of the conterminous United States. 110 p. U.S. Dep. Agric. Anim. and Plant Health Insp. Serv., Plant

Prot. Quar., Washington, D.C.

905. Nash, R. W. 1934. The willow flea weevil, *Orchestes rufipes* LeC., and its control in Maine. J. Econ. Entomol. 27(2): 336-339.

906. Nash, R. W. 1939. The yellow-headed spruce sawfly in Maine. J. Econ. Entomol. 32(2): 330-334.

907. National Academy of Sciences. 1979. Microbial insect control agents. *In* Microbial processes: promising technologies for developing countries. p. 80-106. Natl. Acad. Sci., Washington, D.C.

908. Neal, J. W., Jr. 1982. Rhododendron borer: a worthy competitor. J. Am. Rhododendron Soc. 36:57-60.

909. Needham, J. G., and P. W. Claassen. 1925. A monograph of the Plecoptera or stoneflies of America north of Mexico. 397 p. Thomas Say Foundation, Entomol. Soc. Am., Lafayette, Ind.

910. Needham, J. G., S. W. Frost, and B. H. Tothill. 1928. Leaf-mining insects. 351 p. The Williams and Wilkins Co., Baltimore.

911. Needham, J. G., J. R. Traver, and Yin-Chi Hsu. 1935. The biology of mayflies: with a systematic account of North American species. 759 p. Comstock Publ. Co., Inc., Ithaca, N.Y.

912. Neilson, M. M., B. Martineau, and A. H. Rose. 1971. *Diprion hercyniae* (Hartig), European spruce sawfly (Hymenoptera: Diprionidea). Commonw. Inst. Biol. Control. Tech. Commun. 4:136-143.

913. Neilson, M. M., and R. F. Morris. 1964. The regulation of European spruce sawfly numbers in the maritime provinces of Canada from 1937 to 1963. Can. Entomol. 96(5):773-784.

914. Neiswander, R. B. 1949. The grape mealybug on *Taxus* in Ohio. J. Econ. Entomol. 42(1):41-44.

915. Nelson, G. H. 1975. A revision of the genus *Dicerca* in North America (Coleoptera: Buprestidae). Entomol. Arb. Mus. G. Frey (München) 26:87-180.

916. Nelson, J. C. 1958. Dying of mature eastern hemlock in Cook Forest, Pennsylvania. J. For. 56:344-347.

917. Nelson, R. M. 1934. Effect of bluestain fungi on southern pine attacked by bark beetles. Phytopathol. Z. 7(4):327-353.

918. Nelson, R. M., and J. A. Beal. 1929. Experiments with bluestain fungi in southern pines. Phytopathology 19(12):1101-1106.

919. Nettleton, W. A., and F. P. Hain. 1982. The life history, foliage damage, and control of the balsam twig aphid, *Mindarus abietinus* (Homoptera: Aphididae), in Fraser fir Christmas tree plantations of western North Carolina. Can. Entomol. 114:155-165.

920. Neunzig, H. H. 1970. Redescription of *Acrobasis caryae* Grote and descriptions of three new species of *Acrobasis* (Lepidoptera: Phycitidae). Ann. Entomol. Soc. Am. 63(6): 1656-1664.

921. Neunzig, H. H. 1972. Taxonomy of *Acrobasis* larvae and pupae in eastern North America (Lepidoptera: Pyralidae). U.S. Dep. Agric., Tech. Bull. 1457, 158 p.

922. Neunzig, H. H. 1975. A new species of *Acrobasis* Zeller on river birch (Lepidoptera: Pyralidae: Phycitinae). Proc. Entomol. Soc. Wash. 77(2): 238-245.

923. Neunzig, H. H. 1979. Systematics of immature phycitines (Lepidoptera: Pyralidae) associated with leguminous plants in the southern United States. U.S. Dep. Agric., Tech. Bull. 1589,

119 p.
924. Neunzig, H. H., and E. P. Merkel. 1967. A taxonomic study of the pupae of the genus *Dioryctria* in the Southeastern United States (Lepidoptera: Phycitidae). Ann. Entomol. Soc. Am. 60(4):801-808.
925. Neunzig, H. H., R. L. Rabb, B. H. Ebel, and E. P. Merkel. 1964. Larvae of the genus *Dioryctria* (Lepidoptera: Phycitidae) in the Southeastern United States. Ann. Entomol. Soc. Am. 57(6):693-700.
926. Newell, W. 1899. Some injurious scale insects. Iowa Agric. Coll. Exp. Stn. Bull. 43, p. 143-176.
927. Ngoan, N. D., R. C. Wilkinson, D. E. Short, C. S. Moses, and J. R. Mangold. 1976. Biology of an introduced ambrosia beetle, *Xylosandrus compactus*, in Florida. Ann. Entomol. Soc. Am. 69:872-876.
928. Nichols, J. O. 1980. The gypsy moth. 34 p. Pa. Dep. Environ. Resour. Bur. For., Harrisburg.
929. Nielsen, D. G., and M. J. Dunlap. 1981. Black vine weevil: reproductive potential on selected plants. Ann. Entomol. Soc. Am. 74:60-65.
930. Nielsen, D. G., and N. E. Johnson. 1973. Contribution to the life history and dynamics of pine needle scale, *Phenacaspis pinifoliae*, in central New York. Ann. Entomol. Soc. Am. 66(1):34-43.
931. Nijolt, W. W., L. H. McMullen, and L. Safranyik. 1981. Pine oil protects trees from attack by three bark beetle species, *Dendroctonus* spp. (Coleoptera: Scolytidae). Can. Entomol. 113:337-340.
932. Nord, J. C. 1972. Biology of the Columbian timber beetle, *Corthylus columbianus* (Coleoptera: Scolytidae), in Georgia. Ann. Entomol. Soc. Am. 65(2): 350-358.
933. Nord, J. C. 1973. Population distribution of the Columbian timber beetle, *Corthylus columbianus* (Coleoptera: Scolytidae), within a stand of red maple over seven generations. Ann. Entomol. Soc. Am. 66(3):557-566.
934. Nord, J. C., J. H. Ghent, H. A. Thomas, and C. A. Doggett. 1982. Control of pales and pitch-eating weevils in the South. U.S. Dep. Agric. For. Serv., South. Reg. For. Rep. SA-FR21, 24 p. Atlanta, Ga.
935. Nord, J. C., D. G. Grimble, and F. B. Knight. 1972. Biology of *Oberea schaumii* (Coleoptera: Cerambycidae) in trembling aspen, *Populus tremuloides*. Ann. Entomol. Soc. Am. 65(1): 114-119.
936. Nord, J. C., D. G. Grimble, and F. B. Knight. 1972. Biology of *Saperda inornata* (Coleoptera: Cerambycidae) in trembling aspen, *Populus tremuloides*. Ann. Entomol. Soc. Am. 65(1): 127-135.
937. Nord, J. C., F. B. Knight, and G. B. Vogt. 1965. Identity and biology of an aspen root girdler, *Agrilus horni*. For. Sci. 11(1):33-41.
938. Nord, J. C., I. Ragenovich, and C. A. Doggett. 1984. Pales weevil. U.S. Dep. Agric. For. Serv., For. Insect & Dis. Leafl. 104 rev., 12 p.
939. Nordin, G. L., and J. E. Appleby. 1969. Bionomics of the juniper webworm. Ann. Entomol. Soc. Am. 62(2):287-292.
940. Norris, D. M. 1967. Systemic insecticides in trees. Annu. Rev. Entomol. 12:127-148.
941. Nutting, W. L. 1969. Flight and colony foundation. *In* Biology of termites, vol. 1. p. 233-282. K. Krishna and F. M. Weesner, eds. Academic Press, New York and London.
942. Oatman, E. R., E. F. Legner, and R. F. Brooks. 1962. Bionomics of the eye-spotted bud

moth, *Spilonota ocellana*, on cherry in Wisconsin. J. Econ. Entomol. 55(6):930-934.

943. O'Callaghan, D. P., E. M. Gallagher, and G. N. Lanier. 1980. Field evaluation of pheromone-baited trap trees to control elm bark beetles, vectors of Dutch elm disease. Environ. Entomol. 9:181-185.

944. ODell, T. M., and P. A. Godwin. 1964. White-pine cone beetle. U.S. Dep. Agric. For. Serv., For. Pest Leafl. 83, 7 p.

945. Ohigasna, H., M. R. Wagner, F. Matsumura, and D. M. Benjamin. 1981. Chemical basis of differential feeding behavior of the larch sawfly, *Pristiphora erichsonii* (Hartig). J. Chem. Ecol. 7:599-614.

946. Oliver, A. D. 1964. A behavioral study of two races of the fall webworm, *Hyphantria cunea* (Lepidoptera: Arctiidae), in Louisiana. Ann. Entomol. Soc. Am. 57(2):192-194.

947. Oliver, A. D. 1964. Studies on the biological control of the fall webworm, *Hyphantria cunea*, in Louisiana. J. Econ. Entomol. 57(3):314-318.

948. Ollieu, M. M. 1971. Damage to southern pines in Texas by *Pissodes nemorensis*. J. Econ. Entomol. 64:1456-1459.

949. Osborn, H. 1938. The Fulgoridae of Ohio. Ohio State Univ. Stud., Ohio. Biol. Surv. Bull. 35, 6(6):283-349.

950. Osborn, H. 1940. The Membracidae of Ohio. Ohio State Univ. Stud., Ohio Biol. Surv. Bull. 37, 7(2):51-101.

951. Osgood, E. A., and R. J. Gagné. 1978. Biology and taxonomy of two gall midges (Diptera: Cecidomyiidae) found in galls on balsam fir needles with description of a new species of *Paradiplosis*. Ann. Entomol. Soc. Am. 71(1):85-91.

952. Overgaard, N. A., and L. H. Nachod. 1971. Deodar weevil causes pine mortality in Louisiana. J. Econ. Entomol. 64:1329-1330.

953. Owen, R. B., J. B. Dimond, and A. S. Getchell. 1977. DDT: persistence in northern podosols. J. Environ. Qual. 6:359-360.

954. Pabst, G. S., and P. P. Sikorowski. 1980. Susceptibility of southern pine beetle *(Dendroctonus frontalis)* on oligid medium to *Paecilomyces viridis* and also *Beauvaria bassiana*, and *Metarhizium anisopliae*. J. Ga. Entomol. Soc. 15:235-241.

955. Palmer, M. A. 1952. Aphids of the Rocky Mountain Region. Thomas Say Foundation, vol. V, 452 p. A. B. Hirschfeld Press, Denver, Colo.

956. Parker, D. E. 1936. *Chrysis shanghaiensis* Smith, a parasite of the oriental moth. J. Agric. Res. 52(6):449-458.

957. Parker, D. L. 1935. *Apanteles solitarius* (Ratzeburg), an introduced braconid parasite of the satin moth. U.S. Dep. Agric., Tech. Bull. 477, 18 p.

958. Parr, T. 1937. Notes on the golden or pit-making oak scale. J. For. 35(1):51-58.

959. Parr, T. J. 1939. *Matsucoccus* sp., a scale insect injurious to certain pines in the Northeast (Hemiptera-Homoptera). J. Econ. Entomol. 32(5):624-630.

960. Parrott, P. J., and H. Glasgow. 1916. The leaf-weevil: *(Polydrusus impressifrons* Gyll.). N.Y. Agric. Exp. Stn., Tech. Bull. 56, 24 p.

961. Patch, E. M. 1908. The saddled prominent, *Heterocampa guttivitta* (Walker). Maine Agric. Exp. Stn. Bull. 161, p. 311-350.

962. Patch, E. M. 1910. Gall aphids of the elm. Maine Agric. Exp. Stn. Bull. 181, p. 193-240.

963. Patch, E. M. 1912. Aphid pests of Maine. Maine Agric. Exp. Stn. Bull. 202, p. 159-178.

964. Patch, E. M. 1923. Family Aphididae. *In* Guide to the insects of Connecticut. Part IV. The Hemiptera or sucking insects of Connecticut. W. E. Britton, author. State of Conn., State Geol. & Nat. Hist. Surv. Bull. 34, p. 250-256.

965. Patch, E. M. 1938. Food-plant catalogue of the aphids of the world: including the Phylloxeridae. Maine Agric. Exp. Stn. Bull. 393, p. 35-431.

966. Payne, J. A. 1980. Tree nut pests. *In* Guidelines for control of insect and mite pests of foods, fibers, feeds, ornamentals, livestock, households, forests, and forest products. P. H. Schwartz and D. R. Hamel, eds. U.S. Dep. Agric., Sci. and Educ. Admin., and For. Serv., Agric. Handb. 571, p. 407-426.

967. Payne, J. A., A. S. Menke, and P. M. Schroeder. 1975. *Dryocosmus kuriphilus* Yasumatsu (Hymenoptera: Cynipidae), an oriental chestnut gall wasp in North America. U.S. Dep. Agric., Coop. Econ. Insect Rep. 25, p. 903-905.

968. Payne, J. A., S. G. Polles, and H. Lowman. 1975. Biology and control of the small chestnut weevil, *Curculio sayi* (Coleoptera: Curculionidae). J. Ga. Entomol. Soc. 10:235-241.

969. Payne, T. L. [1981]. Life history and habits. *In* The southern pine beetle. R. C. Thatcher, J. L. Searcy, J. E. Coster, and G. D. Hertel, eds. U.S. Dep. Agric. For. Serv. and Sci. and Educ. Admin. Tech. Bull. 1631, p. 7-28.

970. Peacock, J. W. 1975. Research on chemical and biological controls for elm bark beetles. *In* Dutch elm disease. Proc. IUFRO Conf., Minneapolis-St. Paul, USA, Sept. 1973, p. 18-49, [Publ. by USDA For. Serv., Northeast. For. Exp. Stn., Broomall, Pa.]

971. Peacock, J. W., R. A. Cuthbert, and G. N. Lanier. 1981. Deployment of traps in a barrier strategy to reduce populations of European elm bark beetles and the incidence of Dutch elm disease. *In* Management of insect pests with semiochemicals. p. 155-174. E. R. Mitchell, ed. Plenum Publ. Corp., New York.

972. Pechuman, L. L. 1938. A preliminary study of the biology of *Scolytus sulcatus* LeC. J. Econ. Entomol. 31:537-543.

973. Pechuman, L. L. 1940. Notes on the feeding and breeding habits of *Saperda tridentata* Oliv. Bull. Brooklyn Entomol. Soc. (n.s.) 35(4):113-116.

974. Peck, O. 1963. A catalogue of the Nearctic Chalcidoidea (Insecta: Hymenoptera). Can. Entomol. Suppl. 30:1-1092.

975. Peirson, H. B. 1921. The life history and control of the pales weevil *(Hylobius pales).* Harv. For. Bull. 3, 33 p.

976. Peirson, H. B. 1922. Mound-building ants in forest plantations. J. For. 20(4):325-336.

977. Peirson, H. B., and A. E. Brower. 1936. Biology and control of the birch leaf-mining sawfly. Maine For. Serv. & Maine Hardwood Assoc. Bull. 11, 37 p.

978. Pepper, J. O., and A. N. Tissot. 1973. Pine-feeding species of *Cinara* in the Eastern United States (Homoptera: Aphididae). Fla. Agric. Exp. Stn. Monogr. Ser. 3, 159 p.

979. Peterson, A. 1960. A leaf skeletonizer, *Lobesia liriodendrana* (Kearfott), Olethreutidae, on *Magnolia grandiflora* in Florida. Fla. Entomol. 43(3): 105-114.

980. Peterson, A. 1960. Larvae of insects. Part II. An introduction to Nearctic species: Coleoptera, Diptera, Neuroptera, Siphonaptera, Mecoptera, Trichoptera. 4th ed. 416 p. Edwards Broth-

ers, Inc., Ann Arbor, Mich.

981. Peterson, L. O. T. 1948. Some aspects of poplar borer, *Saperda calcarata* Say, (Cerambycidae) infestations under parkbelt conditions. 78th Annu. Rep. Entomol. Soc. Ont. 1947, p. 56-61.

982. Peterson, L. O. T. 1958. The boxelder twig borer, *Proteoteras willingana* (Kearfott), (Lepidoptera: Olethreutidae). Can. Entomol. 90(11):639-646.

983. Pierce, W. D. 1909. Studies of North American weevils. Proc. U.S. Natl. Mus. 37(1708): 325-364.

984. Pilon, J. G. 1965. Bionomics of the spruce budmoth, *Zeiraphera ratzeburgiana* (Ratz.) Lepidoptera: (Olethreutidae). Phytoprotection 46(1):5-13.

985. Pilon, J. G., and J. R. Blais. 1961. Weather and outbreaks of the spruce budworm in the province of Quebec from 1939-1956. Can. Entomol. 93:118-123.

986. Plumb, G. H. 1950. A new and serious insect pest of red pine. Conn. Agric. Exp. Stn., Spec. Circ., 4 p.

987. Plumb, G. H. 1950. The adult feeding habit of some conifer-infesting weevils. Can. Entomol. 82(3):53-57.

988. Plumb, G. H. 1953. The formation and development of the Norway spruce gall caused by *Adelges abietis* L. Conn. Agric. Exp. Stn. Bull. 566, 77 p.

989. Podgwaite, J. D., and H. M. Mazzone. 1981. Development of insect viruses as pesticides: The case of the gypsy moth *(Lymantria dispar* L.) in North America. Prot. Ecol. 3: 219-227.

990. Podgwaite, J. D., K. S. Shields, and R. A. Lautenschlager. 1981. Epidemiology. *In* The gypsy moth: research toward integrated pest management. C. C. Doane and M. L. McManus, eds. U.S. Dep. Agric. For. Serv., Sci. and Educ. Agency, and Anim. and Plant Health Insp. Serv. Tech. Bull 1584, p. 482-487.

991. Poinar, G. O., Jr. 1975. Entomogenous nematodes. 317 p. E. J. Brill, Publ., Leiden, The Netherlands.

992. Pointing, P. J., and G. W. Green. 1962. A review of the history and biology of the European pine shoot moth, *Rhyacionia buoliana* (Schiff.) (Lepidoptera: Olethreutidae), in Ontario. Proc. Entomol. Soc. Ont. 92:58-69.

993. Potts, S. F. 1958. Concentrated spray equipment, mixtures and application methods. 598 p. Dorland Books, Caldwell, N.J.

994. Potts, S. F., and R. B. Friend. 1946. Mist blowers for applying concentrated spray. Conn. Agric. Exp. Stn. Bull. 501, p. 47-60.

995. Powell, J. A. 1962. Taxonomic studies on the *Acleris gloverana-variana* complex, the black-headed budworms (Lepidoptera: Tortricidae). Can. Entomol. 94(8):833-840.

996. Powell, J. A. 1968. Host associations and taxonomy of Nearctic conifer cone moths of the genus *Eucosma* (Lepidoptera: Tortricidae). Hilgardia 39(1):1-36.

997. Powell, J. A. 1980. Nomenclature of Nearctic conifer-feeding *Choristoneura* (Lepidoptera: Tortricidae): historical review and present status. U.S. Dep. Agric., For. Serv. Gen. Tech. Rep. PNW-100, 18 p. Pacific Northwest For. & Range Exp. Stn., Portland, Oreg.

998. Powell, J. A., and W. E. Miller. 1978. Neartic pine tip moths of the genus *Rhyacionia:* biosystematic review (Lepidoptera: Tortricidae, Olethreutinae). U.S. Dep. Agric., Agric. Handb. 514, 51 p.

999. Prebble, M. L. 1941. The diapause and related phenomena

in *Gilpinia polytoma* (Hartig). Can. J. Res. 19(10):295-322, 323-346; (11):350-362; (12):437-454.

1000. Prebble, M. L., R. E. Balch, G. W. Barter, and others. 1951. Forest entomology in relation to silviculture in Canada. For. Chron. 27(1):6-37.

1001. Prentice, R. M. 1955. The life history and some aspects of the ecology of the large aspen tortrix, *Choristoneura conflictana* (Wlkr.) (N. Comb.) (Lepidoptera: Tortricidae). Can. Entomol. 87(11):461-473.

1002. Prentice, R. M., compiler. 1962. Forest Lepidoptera of Canada. vol. 2. Nycteolidae, Noctuidae, Notodontidae, Liparidae. Can. Dep. For. Bull. 128, p. 77-281. Ottawa.

1003. Prentice, R. M., compiler. 1963. Forest Lepidoptera of Canada: recorded by the forest insect survey. vol 3. Lasiocampidae, Thyatiridae, Drepanidae, Geometridae. Can. Dep. For. Publ. 1013, p. 282-543. Ottawa.

1004. Prentice, R. M., compiler. 1965. Forest Lepidoptera of Canada: reported by the forest insect survey. vol. 4. Microlepidoptera. Can. Dep. For. Publ. 1142, p. 544-840. Ottawa.

1005. Puritch, G. S., and M. T. De L'Armee. 1974. Biocidal effect of fatty acids and soaps on the balsam woolly aphid. Environ. Can. Bi-mon. Res. Note 30:35-36.

1006. Purrington, F. F., and D. G. Nielsen. 1977. Biology of *Podosesia* (Lepidoptera: Sesiidae), with description of a new species from North America. Ann. Entomol. Soc. Am. 70:906-910.

1007. Pyle, R. M. 1981. The Audubon Society field guide to North American butterflies. 516 p. Alfred A. Knopf, New York.

1008. Rabb, R. L., and F. E. Guthrie, eds. 1970. Concepts of pest management. 242 p. Proceedings of a conference held at North Carolina State University, Raleigh, March 25-27, 1970.

1009. Raske, A. G. 1973. *Tetropium parvulum* elevated to species rank and contrasted to *T. cinnamopterum* in morphology and host preference (Coleoptera: Cerambycidae). Can. Entomol. 105(5):745-755.

1010. Raske, A. G., and A. C. Hodson. 1964. The development of *Pineus strobi* (Hartig) (Adelginae, Phylloxeridae) on white pine and black spruce. Can. Entomol. 96(4):599-616.

1011. Rauf, A., and D. M. Benjamin. 1980. The biology of the white pine sawfly, *Neodiprion pinetum* (Hymenoptera: Diprionidae) in Wisconsin. Great Lakes Entomol. 13:219-224.

1012. Ray, C. H., and M. L. Williams. 1980. Description of the immature stages and adult male of *Pseudophilippia quaintancii*. Ann. Entomol. Soc. Am. 73:437-447.

1013. Readio, P. A. 1927. Studies on the biology of the Reduviidae of America north of Mexico. Kans. Univ. Sci. Bull., Part 1, 17(1):5-291.

1014. Reardon, R. C. 1981. Foreign explorations, past history: 1900-1960. *In* The gypsy moth: research toward integrated pest management. C. C. Doane and M. L. McManus, eds. U.S. Dep. Agric. For. Serv., Sci. and Educ. Agency, and Anim. and Plant Health Insp. Serv. Tech. Bull. 1584, p. 301-302.

1015. Reeks, W. A. 1956. Sequential sampling for larvae of the winter moth, *Operophtera brumata* (Linn.) (Lepidoptera: Geometridae). Can. Entomol. 88(6):241-246.

1016. Rehn, J. A. G., and H. J. Grant, Jr. 1961. A monograph of the Orthoptera of North America

(north of Mexico). vol. I. Monogr. Acad. Nat. Sci. Phila. 12, 257 p.

1017. Rennels, R. G. 1960. The Zimmerman pine moth. Univ. Ill. Agric. Exp. Stn. Bull. 660, 39 p.

1018. Retnakaran, A. 1971. Thiotepa as an effective agent for mass sterilizing the spruce budworm, *Choristoneura fumiferana* (Lepidoptera: Tortricidae). Can. Entomol. 103:1753-1756.

1019. Retnakaran, A. 1979. Effect of a new moult inhibitor (EL-494) on the spruce budworm, *Choristoneura fumiferana* (Lepidoptera: Tortricidae). Can. Entomol. 111:847-850.

1020. Retnakaran, A., L. Smith, B. Tomkins, and J. Granett. 1979. Control of forest tent caterpillar, *Malacosoma disstria* (Lepidoptera: Lasiocampidae), with Dimilin®. Can. Entomol. 111:841-846.

1021. Rexrode, C. O. 1976. Insect transmission of oak wilt [caused by the fungus *Ceratocystis fagacearum*], vectors, bark beetles. J. Arboric. 2(4):61-66.

1022. Rexrode, C. O., and T. W. Jones. 1970. Oak bark beetles—important vectors of oak wilt. J. For. 68(5):294-297.

1023. Rexrode, C. O., H. M. Kulman, and C. K. Dorsey. 1965. Bionomics of the bark beetle *Pseudopityophthorus pruinosus* with special reference to its role as a vector of oak wilt, *Ceratocystis fagacearum*. J. Econ. Entomol. 58(5):913-916.

1024. Richards, A. M. 1962. The oyster-shell scale, *Quadraspidiotus ostreaeformis* (Curtis), in the Christchurch District of New Zealand. N. Z. J. Agric. Res. 5(1-2):95-100.

1025. Richards, W. R. 1960. A new species of *Matsucoccus* Cockerell (Homoptera: Coccoidea). Can. Entomol. 92(3):179-181.

1026. Richerson, J. V., F. A. McCarty, and T. L. Payne. 1980. Disruption of southern pine beetle infestations with frontalure. Environ. Entomol. 9:90-93.

1027. Riley, C. V. 1871. Third annual report on the noxious, beneficial, and other insects of the State of Missouri. 175 p. Horace Wilcox, Public Printer, Jefferson City, Mo.

1028. Riley, C. V. 1894. Notes on Coccidae. Proc. Entomol. Soc. Wash. 3(1):65-71.

1029. Riotte, J. C. E., and R. S. Peigler. 1981. A revision of the American genus *Anisota* (Saturniidae). J. Res. Lepid. 19: 101-180.

1030. Ritcher, P. O. 1940. Kentucky white grubs. Ky. Agric. Exp. Stn. Bull. 401, p. 71-157.

1031. Robertson, J. L., and R. A. Kimball. 1981. Variables affecting the practical use of juvenile hormone analogues for control of the western spruce budworm *(Choristoneura occidentalis)* (Lepidoptera: Tortricidae). Can. Entomol. 113:827-844.

1032. Rockburne, E. W., and J. D. LaFontaine. 1976. The cutworm moths of Ontario and Quebec. Can. Dep. Agric., Res. Branch Publ. 1593, 164 p. Ottawa, Ont.

1033. Rollinson, W. D., F. B. Lewis, and W. E. Waters. 1965. The successful use of a nuclear-polyhedrosis virus against the gypsy moth. J. Invertebr. Pathol. 7(4):515-517.

1034. Rose, A. H. 1957. Some notes on the biology of *Monochamus scutellatus* (Say) (Coleoptera: Cerambycidae). Can. Entomol. 89(12):547-553.

1035. Rose, A. H. 1958. The effect of defoliation on foliage production and radial growth of quaking aspen. For. Sci. 4(4): 335-342.

1036. Rose, A. H., and O. H. Lindquist. 1977. Insects of eastern spruces, fir and hemlock. Can. For. Serv., For. Tech. Rep. 23,

159 p. Ottawa.

1037. Rose, A. H., and O. H. Lindquist. 1980. Insects of eastern larch, cedar and juniper. Can. For. Serv., For. Tech. Rep. 28, 100 p. Ottawa.

1038. Rosel, A. 1962. Laboratory breeding of *Lyctus brunneus* (Steph.). Pest Tech. 4(4):78-82.

1039. Ross, D. A. 1962. Bionomics of the maple leaf cutter, *Paraclemensia acerifoliella* (Fitch), (Lepidoptera: Incurvariidae). Can. Entomol. 94(10): 1053-1063.

1040. Ross, D. A., and J. S. Downton. 1966. Protecting logs from long-horned wood borers with lindane emulsion. For. Chron. 42:377-379.

1041. Ross, H. H. 1937. A generic classification of the Nearctic sawflies (Hymenoptera, Symphata) [with seventeen plates]. Ill. Biol. Monogr. 15(2):1-173.

1042. Ross, H. H. 1955. The taxonomy and evolution of the sawfly genus *Neodiprion*. For. Sci. 1(3):196-209.

1043. Ross, H. H. 1956. A textbook of entomology. 2d ed. 519 p. John Wiley & Sons, Inc., New York.

1044. Rumbold, C. T. 1931. Two blue-staining fungi associated with bark-beetle infestation of pines. J. Agric. Res. 43(10): 847-873.

1045. Russell, L. M. 1941. A classification of the scale insect genus Asterolecanium. U.S. Dep. Agric., Misc. Publ. 424, 322 p.

1046. Ryan, R. B. 1980. Rearing methods and biological notes for seven species of European and Japanese parasites of the larch casebearer (Lepidoptera: Coleophoridae). Can. Entomol. 112:1239-1248.

1047. Ryan, R. B., W. E. Bousfield, C. W. Johanningmeir, G. B. Parsons, R. F. Schmitz, and L. J. Theroux. 1977. Releases of recently imported larch casebearer parasites for biological control in the western United States, including relocations of *Agathis pumila*. U.S. Dep. Agric., For. Serv. Res. Note PNW-290, 8 p. Pacific Northwest For. & Range Exp. Stn., Portland, Oreg.

1048. Sabrosky, C. W. 1952. How many insects are there? *In* Insects. U.S. Dep. Agric., Yearb. Agric. 1952, p. 1-7.

1049. Sabrosky, C. W., and P. H. Arnaud, Jr. 1965. Family Tachinidae (Larvaevoridae). *In* A catalog of the Diptera of America north of Mexico. U.S. Dep. Agric., Agric. Handb. 276, p. 961-1108.

1050. St. George, R. A., H. R. Johnston, and R. J. Kowal. 1963. Subterranean termites, their prevention and control in buildings. U.S. Dep. Agric., Home & Garden Bull. 64 rev., 30 p.

1051. Salman, K. A., and J. W. Bongberg. 1942. Logging high-risk trees to control insects in the pine stands of northeastern California. J. For. 40(7): 533-539.

1052. Sanders, C. J. 1964. The biology of carpenter ants in New Brunswick. Can. Entomol. 96(6):894-909.

1053. Sands, W. A. 1969. The association of termites and fungi. *In* Biology of termites, vol. 1, p. 495-524. K. Krishna and F. M. Weesner, eds. Academic Press, New York and London.

1054. Sapio, F. J., L. F. Wilson, and M. E. Ostry. 1982. A split-stem lesion on young hybrid *Populus* trees caused by the tarnished plant bug, *Lygus lineolaris* (Palisot de Beauvois). Great Lakes Entomol. 15(4):237-246.

1055. Sargent, T. D. 1976. Legion of night; the underwing moths. 232 p. Univ. Mass. Press, Amherst.

1056. Saylor, L. W. 1945. Revision of the scarab beetles of the genus *Dichelonyx*. Bull. Brooklyn En-

tomol. Soc., (n.s.) 40(5): 137-158.

1057. Schaber, B. D., and F. E. Wood. 1971. A new species of *Dioryctria* infesting loblolly pine (Lepidoptera: Pyralidae). Proc. Entomol. Soc. Wash. 73: 215-223.

1058. Schaefer, C. H. 1964. Studies on the life history of the Virginia pine sawfly *(Neodiprion pratti* Dyar). U.S. Dep. Agric. For. Serv., Res. Pap. WO-2, 8 p. Washington, D.C.

1059. Schaffner, J. V., Jr. 1936. European sawfly *Pristiphora geniculata* attacks mountain ash in the United States. J. Econ. Entomol. 29(2):469.

1060. Schaffner, J. V., Jr. 1939. *Neodiprion sertifer* (Geoff.), a pine sawfly accidentally introduced into New Jersey from Europe. J. Econ. Entomol. 32(6):887-888.

1061. Schaffner, J. V., Jr. 1944. *Diprion frutetorum* (F.). Conn. Agric. Exp. Stn. Bull. 481, p. 307-313.

1062. Schaffner, J. V., Jr. 1959. Microlepidoptera and their parasites reared from field collections in the Northeastern United States. U.S. Dep. Agric., Misc. Publ. 767, 97 p.

1063. Schaffner, J. V., Jr., and C. L. Griswold. 1934. Macrolepidoptera and their parasites reared from field collections in the northeastern part of the United States. U.S. Dep. Agric., Misc. Publ. 188, 160 p.

1064. Schaffner, J. V., Jr., and H. L. McIntyre. 1944. The pine root-collar weevil. J. For. 42(4):269-275.

1065. Schenk, J. A., and D. M. Benjamin. 1969. Notes on the biology of *Ips pini* in central Wisconsin jack pine forests. Ann. Entomol. Soc. Am. 62(3):480-485.

1066. Schmutterer, H. 1959. Schildläuse oder Coccoidea: I. Deckelschildläuse oder Diaspididae. Die Tierwelt Deutschland und der Agrenzenden Meeresteile. Teil 45, 260 p. [Veb Gustav Fischer Verlag, Jena, Germany.]

1067. Schneider, J. C. 1980. The role of parthenogenesis and female aptery in microgeographic, ecological adaptation in the fall cankerworm, *Alsophila pometaria* Harris (Lepidoptera: Geometridae). Ecology 61:1082-1090.

1068. Schread, J. C. 1961. Scales and mealybugs. Conn. Agric. Exp. Stn. Circ. 216, 11 p.

1069. Schreiber, L. R., and J. W. Peacock. 1975. Dutch elm disease and its control. U.S. Dep. Agric., Inf. Bull. 193 rev., 15 p.

1070. Schultz, D. E., and D. C. Allen. 1975. Biology and descriptions of the cherry scallop shell moth, *Hydria prunivorata* (Lepidoptera: Geometridae), in New York. Can. Entomol. 107(1): 99-106.

1071. Schultz, D. E., and D. C. Allen. 1977. Effects of defoliation by *Hydria prunivorata* on the growth of black cherry. Environ. Entomol. 6:276-283.

1072. Schwalbe, C. P. 1981. Disparlure-baited traps for survey and detection. *In* The gypsy moth: research toward integrated pest management. C. C. Doane and M. L. McManus, eds. U.S. Dep. Agric. For. Serv., Sci. and Educ. Agency, and Anim. and Plant Health Insp. Serv. Tech. Bull. 1584, p. 542-549.

1073. Schwalbe, C. P. 1982. Sterile male technique. *In* Proc. Southern conference on gypsy moth. p. 60-61. H. M. Singletary, Jr., J. R. McGraw, C. A. Doggett, F. P. Planer, and P. J. Barry, eds., N.C. Dep. Agric., Raleigh.

1074. Schwerdtfager, F. 1973. Forest entomology. *In* History of entomology. p. 361-387. R. F. Smith, T. E. Mittler, and C. N.

Smith, eds. Annual Reviews, Inc., Palo Alto, Calif.

1075. Selman, C. L. 1975. A pictorial key to the hawkmoths (Lepidoptera: Sphingidae) of eastern United States (except Florida). Ohio Biol. Surv. Biol. Notes 9, 31 p.

1076. Sharma, G. D., A. T. Drooz, and A. E. Treat. 1983. A new species of *Callidosoma* (Acari: Prostigma: Erythraeidae) parasite on adults of *Anacamptodes vellivolata* (Lepidoptera: Geometridae) as a larva, and predator of eggs of Lepidoptera as deutonymph and adult. Ann. Entomol. Soc. Am. 76: 120-129.

1077. Shaw, F. R., and J. Weidhaas, Jr. 1956. Distribution and habits of the giant hornet in North America. J. Econ. Entomol. 49(2):275.

1078. Shenefelt, R. D., and D. M. Benjamin. 1955. Insects of Wisconsin forests. Wis. Agric. Ext. Serv. Circ. 500, 110 p.

1079. Shigo, A. L. 1962. Another scale insect on beech. U.S. Dep. Agric. For. Serv., Stn. Pap. 168, 13 p. Northeast. For. Exp. Stn., Broomall, Pa.

1080. Shigo, A. L. 1970. Beech bark disease. U.S. Dep. Agric. For. Serv., For. Pest Leafl. 75 rev., 8 p.

1081. Silver, G. T. 1957. Studies on the arborvitae leaf miners in New Brunswick (Lepidoptera: Yponomeutidae and Gelechiidae). Can. Entomol. 89(4):171-182.

1082. Silverstein, R. M., R. G. Brownlee, T. E. Bellas, D. L. Wood, and L. E. Browne. 1968. Brevicomin: principal sex attractant in the frass of the female western pine beetle. Science 159(3817):889-891.

1083. Simeone, J. B. 1954. Carpenter ants and their control. State Univ. N.Y. Coll. For. at Syracuse, Univ. Bull. 34, 19 p.

1084. Simeone, J. B. 1960. Observations on *Hadrobregmus carinatus* (Say) and other wood-feeding Anobiidae (Coleoptera) in the Northeastern United States. Ph.D. Diss. Cornell Univ., Ithaca, N.Y. 183 p.

1085. Simeone, J. B. 1961. An introduced species of *Ptilinus* from New York (Coleoptera: Anobiidae). Can. Entomol. 93(6):428-430.

1086. Simeone, J. B. 1962. Survey of wood-feeding Anobiidae in Northeastern United States, including a study of temperature and humidity effects on egg development of *Hadrobregmus carinatus* (Say). 11th Int. Kongr. Entomol., Wien, 17-25 Aug. 1960, Verh. Band II, p. 326-335.

1087. Simeone, J. B. 1965. The frass of northeastern United States powder posting beetles. 12th Int. Congr. Entomol., London, 8-16 July 1964, Proc., p. 707-708.

1088. Simeone, J. B., and J. H. Engelken. 1959. Injury to coniferous tree seedlings by the oblique-banded leaf roller. J. For. 57(7):492-494.

1089. Simmons, G. A., and F. B. Knight. 1973. Deformity of sugar maple caused by bud feeding insects. Can. Entomol. 105:1559-1566.

1090. Simons, E. E., R. C. Reardon, and M. Ticehurst. 1979. Selected parasites and hyperparasites of the gypsy moth, with keys to adults and immatures. U.S. Dep. Agric., Agric. Handb. 540, 59 p.

1091. Sinclair, W. A., and R. J. Campana. 1978. Dutch elm disease: Perspectives after 60 years. Search Agric. 8(5):3-52. New York Agric. Exp. Stn., Cornell Univ., Ithaca, N.Y.

1092. Sloop, K. D. 1937. A revision of the North American buprestid beetles belonging to the genus

Melanophila (Coleoptera, Buprestidae). Univ. Calif. Publ. Entomol. 7(1):1-19.

1093. Smereka, E. P. 1965. The life history and habits of *Chrysomela crotchi* Brown (Coleoptera: Chrysomelidae) in northwestern Ontario. Can. Entomol. 97:541-549.

1094. Smirnoff, W. A. 1966. *Thelohania pristiphorae* sp.n., a microsporidian parasite of the larch sawfly, *Pristiphora erichsonii* (Hymenoptera: Tenthredinidae). J. Invert. Pathol. 8:360-364.

1095. Smirnoff, W. A., J. J. Fettes, and W. Haliburton. 1962. A virus disease of Swaine's jack pine sawfly, *Neodiprion swainei* Midd. sprayed from an aircraft. Can. Entomol. 94(5):477-486.

1096. Smith, B. D., and K. G. Scott. 1964. The life history and behavior of the willow weevil, *Cryptorhynchus lapathi* (L.) Ann. Appl. Biol. 54:141-151.

1097. Smith, D. R. 1971. Nearctic sawflies III. Heterarthrinae: adults and larvae (Hymenoptera: Tenthredinidae). U.S. Dep. Agric., Agric. Res. Serv. Tech. Bull. 1420, 84 p. Washington, D.C.

1098. Smith, D. R. 1972. Sawflies of the genus *Croesus* Leach in North America. Proc. Entomol. Soc. Wash. 74:169-180.

1099. Smith, D. R. 1974. Conifer sawflies, Diprionidae: key to North American genera, checklist of world species, and new species from Mexico (Hymenoptera). Proc. Entomol. Soc. Wash. 76(4):409-418.

1100. Smith, D. R. 1975. *Eriotremex formosanus* (Matsumura), an Asian horntail in North America (Hymenoptera: Siricidae). U.S. Dep. Agric., Coop. Econ. Insect Rep. 25(44):851-854.

1101. Smith, D. R. 1975. The sawfly genus *Hemichroa* Stephens: a review of species (Hymenoptera: Tenthredinidae). Entomol. Scand. 6:297-302.

1102. Smith, D. R. 1976. The xiphydriid woodwasps of North America. Trans. Am. Entomol. Soc. 102:101-131.

1103. Smith, D. R., C. P. Obmart, and D. L. Dahlsten. 1977. The shoot-boring sawflies of the genus *Pleroneura* in North America (Hymenoptera: Xyelidae). Ann. Entomol. Soc. Am. 70:761-767.

1104. Smith, F. F. 1932. Biology and control of the black vine weevil. U.S. Dep. Agric., Tech. Bull. 325, 45 p.

1105. Smith, F. F., A. K. Ota, C. W. McComb, and J. A. Weidhaas, Jr. 1971. Development and control of a wax scale, *Ceroplastes ceriferus*. J. Econ. Entomol. 64(4):889-893.

1106. Smith, H. R., and R. A. Lautenschlager. 1981. Gypsy moth predators. *In* The gypsy moth: research toward integrated pest management. C. C. Doane and M. L. McManus, eds. U.S. Dep. Agric. For. Serv., Sci. and Educ. Agency, and Anim. and Plant Health Insp. Serv. Tech. Bull. 1584, p. 96-125.

1107. Smith, H. S. 1912. Technical results from the gypsy moth parasite laboratory. IV. The Chalcidoid genus *Perilampus* and its relations to the problem of parasite introduction. U.S. Bur. Entomol., Tech. Ser. 19, p. 33-69.

1108. Smith, J. B., and H. G. Dyar. 1899. Contributions toward a monograph of the lepidopterous family Noctuidae of boreal North America. A revision of the species of *Acronycta* (Ochsenheimer) and of certain allied genera. Proc. U.S. Natl. Mus. 21(1140):1-194.

1109. Smith, M. R. 1947. A generic and subgeneric synopsis of the United States ants, based on workers (Hymenoptera: Formicidae). Am. Midl. Nat.

37(3):521-647.

1110. Smith, M. R. 1965. House-infesting ants of the Eastern United States: their recognition, biology, and economic importance. U.S. Dep. Agric., Tech. Bull. 1326, 105 p.

1111. Smith, R. C. 1922. The biology of the Chrysopidae. Cornell Univ. Agric. Exp. Stn. Memo. 58:1285-1376. Ithaca, N.Y.

1112. Smith, R. C., and R. S. Taylor. 1953. The biology and control of the hackberry psyllids in Kansas. J. Kans. Entomol. Soc. 26(3):103-115.

1113. Smith, R. H. 1956. The rearing of *Lyctus planicollis* and the preparation of wood for control tests. J. Econ. Entomol. 49(1):127-129.

1114. Smith, R. H. 1960. Resistance of pines to the pine reproduction weevil, *Cylindrocopturus eatoni*. J. Econ. Entomol. 53(6):1044-1048.

1115. Smith, R. H. 1961. Red turpentine beetle. U.S. Dep. Agric. For. Serv., For. Pest Leafl. 55, 8 p.

1116. Smith, R. H. 1963. Toxicity of pine resin vapors to three species of *Dendroctonus* bark beetles. J. Econ. Entomol. 56(6):827-831.

1117. Smith, R. H. 1965. Effect of monoterpene vapors on the western pine beetle. J. Econ. Entomol. 58(3):509-510.

1118. Smith, R. H. 1966. The monoterpene composition of *Pinus ponderosa* xylem resin and of *Dendroctonus brevicomis* pitch tubes. For. Sci. 12(1):63-68.

1119. Smith, R. H., and R. E. Lee. 1967. Black turpentine beetle. U.S. Dep. Agric. For. Serv., For. Pest Leafl. 12 rev., 7 p.

1120. Smith, S. G., and B. A. Sugden. 1969. Host trees and breeding sites of native North American *Pissodes* bark weevils, with a note on synonyomy. Ann. Entomol. Soc. Am. 62(1):146-148.

1121. Smythe, R. V., F. L. Carter, and C. C. Baxter. 1971. Influence of wood decay on feeding and survival of the eastern subterranean termite, *Reticulitermes flavipes* (Isoptera: Rhinotermitidae). Ann. Entomol. Soc. Am. 64(1):59-62.

1122. Snyder, T. E. 1934. The drywood termites of Eastern and Southern United States. *In* Termites and termite control. 2d ed., rev. p. 269-272. C. A. Kofoid, ed. Univ. Calif. Press, Berkeley.

1123. Snyder, T. E. 1935. An introduced anobiid beetle destructive to houses in the Southern States. Proc. Biol. Soc. Wash. 48: 59-60.

1124. Snyder, T. E. 1950. Control of nonsubterranean termites. U.S. Dep. Agric., Farmers' Bull. 2018, 16 p.

1125. Sohi, S. S., and G. G. Wilson. 1976. Persistent infection of *Malacosoma disstria* (Lepidoptera: Lasiocampidae) cell cultures with *Nosema (Glugea) disstriae* (Microsporidia: Nosematidae). Can. J. Zool. 54:336-342.

1126. Solomon, J. D. 1968. Cerambycid borer in mulberry. J. Econ. Entomol. 61(4): 1023-1025.

1127. Solomon, J. D. 1972. Biology and habits of the living beech borer in red oaks. J. Econ. Entomol. 65(5):1307-1310.

1128. Solomon, J. D. 1974. Biology and damage of the hickory borer, *Goes pulcher,* in hickory and pecan. Ann. Entomol. Soc. Am. 67(2):257-260.

1129. Solomon, J. D. 1977. Biology and habits of the oak branch borer *(Goes debilis)*. Ann. Entomol. Soc. Am. 70:57-59.

1130. Solomon, J. D. 1980. Cottonwood borer *(Plectrodera scalator)* —a guide to its biology, damage, and control. U.S. Dep.

Agric., For. Serv. Res. Pap. SO-157, 10 p. South. For. Exp. Stn., New Orleans, La.

1131. Solomon, J. D. 1980. Management of insect pests in midsouth upland hardwoods. Proceedings, mid-South upland hardwood symposium for the practicing forester and land manager. U.S. Dep. Agric., For. Serv. Tech. Publ. SA-TP 12, p. 152-160. Southeast. Area, State & Priv. For., Atlanta, Ga.

1132. Solomon, J. D., J. R. Cook, F. L. Oliveria, and T. H. Filer. 1976. Insect and disease impact in cottonwood nurseries. *In* Proceedings symposium eastern cottonwood and related species, p. 301-307. B. A. Thielges and S. Bland, eds. and comp. Poplar Counc. North Am., La. State Univ., Div. Contin. Educ., Baton Rouge, La.

1133. Solomon, J. D., F. I. McCracken, R. L. Anderson, R. Lewis, F. L. Oliveria, T. H. Filer, and P. J. Barry. 1980. Oak pests: a guide to major insects, diseases, air pollution and chemical injury. U.S. Dep. Agric., For. Serv. Gen. Tech. Rep. SA-GR 11, 69 p. Southeast. Area, State & Priv. For., Atlanta, Ga.

1134. Solomon, J. D., and R. C. Morris. 1965. White oak borer in Mississippi. Miss. Agric. Exp. Stn., Inf. Sheet 908, 2 p.

1135. Solomon, J. D., and R. C. Morris. 1966. Clearwing borer in red oaks. U.S. Dep. Agric. For. Serv., Res. Note SO-39, 3 p. South. For. Exp. Stn., New Orleans, La.

1136. Solomon, J. D., and W. K. Randall. 1978. Biology and damage of the willow shoot sawfly in willow and cottonwood. Ann. Entomol. Soc. Am. 71: 654-657.

1137. Sparks, D., J. A. Payne, and L. S. Jones. 1974. Association of *Prionus* root borers with nutrition, growth and yield of pecan, *Carya illinoensis* Koch. HortScience 9(3):197-199.

1138. Speers, C. F. 1941. The pine spittle bug *(Aphrophora parallela* Say). Bull. N.Y. State Coll. For. at Syracuse Univ., Tech. Publ. 54, 65 p.

1139. Speers, C. F. 1974. Pales and pitcheating weevils: development in relation to time pines are cut in the Southeast. U.S. Dep. Agric. For. Serv., Res. Note SE-207, 7 p. Southeast. For. Exp. Stn., Asheville, N.C.

1140. Speers, C. F., and E. P. Merkel. 1974. How to prevent weevil damage to pine seedlings in the South. U.S. Dep. Agric. For. Serv., Gen. Tech. Rep. SE-5 [11 p.] Southeast. For. Exp. Stn., Asheville, N.C.

1141. Speers, C. F., and D. C. Schmiege. 1961. White grubs in forest tree nurseries and plantations. U.S. Dep. Agric. For. Serv., For. Pest Leafl. 63, 4 p.

1142. Spink, W. T., H. R. Gross, and L. D. Kirst. 1966. Can water emulsions of chlorinated hydrocarbon insecticides control the wood-boring beetle *Xyletinus peltatus* (Harris) in structural timbers? Pest Control 34(2):12-13,15,44,46.

1143. Sreenivasam, D. D., D. M. Benjamin, and D. D. Walgenbach. 1972. The bionomics of the pine tussock moth. Univ. Wis. Res. Bull. 282, 36 p.

1144. Stairs, G. R. 1965. Artificial initiation of virus epizootics in forest tent caterpillar populations. Can. Entomol. 97(10): 1059-1062.

1145. Stairs, G. R. 1971. Use of viruses for microbial control of insects. *In* Microbial control of insects and mites. p. 97-123. H. D. Burges and N. W. Hussey, eds., Academic Press, New York.

1146. Stannard, L. J., Jr. 1965. Poly-

morphism in the Putnam's scale, *Aspidiotus ancylus* (Homoptera: Coccoidea). Ann. Entomol. Soc. Am. 58(4):573-576.

1147. Stark, E. J., and J. D. Harper. 1982. Pupal mortality in forest tent caterpillar (Lepidoptera: Lasiocampidae): causes and impact on populations in southwestern Alabama. Environ. Entomol. 11:1071-1077.

1148. Stearns, L. A. 1923. Family Cercopidae. *In* Guide to the insects of Connecticut. Part IV. The Hemiptera or sucking insects of Connecticut. W. E. Britton. State of Conn., State Geol. & Nat. Hist. Surv. Bull. 34, p. 206-238.

1149. Stehr, F. W., and E. F. Cook. 1968. A revision of the genus *Malacosoma* Hübner in North America (Lepidoptera: Lasiocampidae): Systematics, biology, immatures, and parasites. U.S. Natl. Mus. Bull. 276, 321 p.

1150. Stehr, G. W. 1967. On coniferophagous species of *Choristoneura* (Lepidoptera: Tortricidae) in North America. II. Geographic distribution in accordance with forest regions. Can. Entomol. 99(5):456-463.

1151. Stehr, W. C. 1930. The Coccinellidae (ladybird beetles) of Minnesota (Coleoptera). Univ. Minn. Agric. Exp. Stn., Tech. Bull. 75, 54 p.

1152. Stein, J. D. 1974. Elm sawfly. U.S. Dep. Agric. For. Serv., For. Pest Leafl. 142, 6 p.

1153. Steinhaus, E. A. 1949. Principles of insect pathology. 757 p. McGraw-Hill Book Co., Inc., New York, Toronto, London.

1154. Steinweden, J. B. 1929. Bases for the generic classification of the coccoid family Coccidae. Ann. Entomol. Soc. Am. 22(2):197-245.

1155. Stephen, F. M., J. L. Searcy, and G. D. Hertel, eds. 1980. Modeling southern pine beetle populations: symposium proceedings. [Asheville, N.C., February 1980.] U.S. Dep. Agric. For. Serv., Tech. Bull. 1630, 174 p.

1156. Stephens, G. R. 1971. The relation of insect defoliation to mortality in Connecticut forests. Conn. Agric. Exp. Stn. Bull. 723, 16 p.

1157. Stephenson, A. G. 1980. Fruit set, herbivory, fruit production, and the fruiting strategy of *Catalpa speciosa* (Bignoniaceae). Ecology 61:57-64.

1158. Stevens, R. E., and R. W. Stark. 1962. Sequential sampling for the lodgepole needle miner, *Evagora milleri*. J. Econ. Entomol. 55(4):491-494.

1159. Stillwell, M. A. 1966. Woodwasps (Siricidae) in conifers and the associated fungus, *Stereum chailletii*, in eastern Canada. For. Sci. 12:121-128.

1160. Stillwell, M. A. 1967. The pigeon tremex, *Tremex columba* (Hymenoptera: Siricidae), in New Brunswick. Can. Entomol. 99:685-689.

1161. Stimmann, M. W. 1969. Seasonal history of a unisexual population of the pine needle scale, *Phenacaspis pinifoliae*. Ann. Entomol. Soc. Am. 62(4): 930-931.

1162. Stimmel, J. F. 1979. Seasonal history and distribution of *Carulaspis minima* (Targ.-Tozz.) in Pennsylvania. Proc. Entomol. Soc. Wash. 81:222-229.

1163. Stimmel, J. F. 1981. First record of the red pine scale, *Matsucoccus resinosae*, from Pennsylvania. Proc. Entomol. Soc. Wash. 83:804.

1164. Stimmel, J. F. 1982. Seasonal history of the white peach scale, *Pseudaulacaspis pentagona*, in northeastern Pennsylvania. Proc. Entomol. Soc. Wash. 84:128-133.

1165. Stock, M. W., and P. J. Castrovillo. 1981. Genetic rela-

tionships among representative populations of five *Choristoneura* species: *C. occidentalis, C. retiniana, C. biennis, C. lambertiana*, and *C. fumiferana* (Lepidoptera: Tortricidea). Can. Entomol. 113:857-865.

1166. Stock, M. W., and J. L. Robertson. 1979. Differential response of Douglas-fir tussock moth, *Orgyia psuedotsugata* (Lepidoptera: Lymantriidae), populations and sibling groups to acephate and carbaryl: toxicological and genetic analysis. Can. Entomol. 111:1231-1239.

1167. Stock, M. W., and J. L. Robertson. 1980. Inter- and intraspecific variation in selected *Choristoneura* species (Lepidoptera: Tortricidae): a toxicological and genetic survey. Can. Entomol. 112:1019-1027.

1168. Stoetzel, M. B. 1975. Seasonal history of seven species of armored scale insects of the Aspidiotini (Homoptera: Diaspididae). Ann. Entomol. Soc. Am. 68(3):489-492.

1169. Stoetzel, M. B. 1976. Scale-cover formation in the Diaspididae (Homoptera: Coccoidea). Proc. Entomol. Soc. Wash. 78(3):323-332.

1170. Stoetzel, M. B., and J. A. Davidson. 1971. Biology of the obscure scale, *Melanaspis obscura* (Homoptera: Diaspididae), on pin oak in Maryland. Ann. Entomol. Soc. Am. 64(1):45-50.

1171. Stoetzel, M. B., and J. A. Davidson. 1973. Life history variations of the obscure scale (Homoptera: Diaspididae) on pin oak and white oak in Maryland. Ann. Entomol. Soc. Am. 66(2):308-311.

1172. Stoetzel, M. B., and J. A. Davidson. 1974. Biology, morphology and taxonomy of immature stages of 9 species in the Aspidiotini (Homoptera: Diaspididae). Ann. Entomol. Soc. Am. 67(3):475-509.

1173. Stone, A. 1965. Family Culicidae. *In* A catalog of the Diptera of America north of Mexico. U.S. Dep. Agric., Agric. Handb. 276, p. 105-120.

1174. Stone, A. 1965. Family Simuliidae. *In* A catalog of the Diptera of America north of Mexico. U.S. Dep. Agric., Agric. Handb. 276, p. 181-189.

1175. Stone, A., C. W. Sabrosky, W. W. Wirth, and others. 1965. A catalog of the Diptera of America north of Mexico. U.S. Dep. Agric., Agric. Handb. 276, 1696 p.

1176. Struble, G. R., and P. C. Johnson. 1964. Black pine-leaf scale. U.S. Dep. Agric. For. Serv., For. Pest Leafl. 91, 6 p.

1177. Sublette, J. E., and M. S. Sublette. 1965. Family Chironomidae (Tendipedidae). *In* A catalog of the Diptera of America north of Mexico. U.S. Dep. Agric., Agri. Handb. 276, p. 142-181.

1178. Sullivan, C. R., and D. R. Wallace. 1972. The potential northern dispersal of the gypsy moth, *Porthetria dispar.* Can. Entomol. 104:1349-1355.

1179. Surgeoner, G. A., and W. E. Wallner. 1978. Foliage consumption by the variable oakleaf caterpillar, *Heterocampa manteo* (Lepidoptera: Notedontidae); its use in defoliation prediction. Can. Entomol. 110:241-244.

1180. Swain, K. M., and M. C. Remion. 1981. Direct control methods for the southern pine beetle. U.S. Dep. Agric., Comb. For. Pest Res. & Dev. Program, Agric. Handb. 575, 15 p.

1181. Swaine, J. M. 1924. The control of the destructive spruce bark beetle in eastern Canada. Can. Dep. Agric. Pam. (n.s.) 48, 19 p.

1182. Swaine, J. M., F. C. Craighead, and I. W. Bailey. 1924. Studies on the spruce budworm (*Cacoecia fumiferana* Clem.). Parts I and II. Can. Dep. Agric., Entomol. Branch. Tech. Bull. (n.s.) 37, 91 p.

1183. Sweetman, H. L. 1958. The principles of biological control. Interrelation of hosts and pests and utilization in regulation of animal and plant populations. 560 p. Wm. C. Brown Co., Dubuque, Iowa.

1184. Syme, P. D. 1971. *Rhyacionia buoliana* (Schiff.), European pine shoot moth (Lepidoptera: Olethreutidae). *In* Biological control programmes against insects and weeds in Canada 1959-1968. Commonw. Inst. Biol. Control, Agric. Bur. Tech. Commun. 4, p. 194-205. [Commonw. Agric. Bur., Farnham Royal, Slough, England.]

1185. Takago, S., and J. O. Howell. 1977. The genus *Quernaspis*, a possible new Asio-American element in scale insect biogeography. Insecta Matsumurana (n.s.) 11:31-59.

1186. Talerico, R. L. 1962. A study of damage caused by the sugar-maple borer. J. For. 60(3):178-180.

1187. Talerico, R. L. 1968. Life history of the looper *Phigalia titea* in Virginia. Ann. Entomol. Soc. Am. 61(3):557-561.

1188. Tashiro, H. 1974. Biology and control of the spruce needleminer. J. Econ. Entomol. 67(1):89-92.

1189. Tashiro, H., G. G. Gyrisco, F. L. Gambrell, B. J. Fiori, and H. Breitfeld. 1969. Biology of the European chafer, *Amphimallon majalis* (Coleoptera: Scarabaeidea), in northeastern United States. N.Y. Agric. Exp. Stn. Bull. 828, 71 p. Geneva, N.Y.

1190. Taylor, J. W., Jr., and R. T. Franklin. 1970. Biology of *Hylobius pales* (Coleoptera: Curculionidae), in the Georgia Piedmont. Can. Entomol. 102:729-735.

1191. Taylor, R. L. 1929. The biology of the white pine weevil, *Pissodes strobi* (Peck), and a study of its insect parasites from an economic viewpoint. Entomol. Am. (n.s.) 9(4):67-246; 10(1):1-86.

1192. Teskey, H. J. 1976. Diptera larvae associated with trees in North America. Mem. Entomol. Soc. Can. 100, 53 p.

1193. Thatcher, R. C. 1960. Influence of the pitch-eating weevil on pine regeneration in east Texas. For. Sci. 6(4):354-361.

1194. Thatcher, R. C. 1971. Pine sawfly *Neodiprion excitans* Roh. U.S. Dep. Agric. For. Serv., For. Pest Leafl. 105 rev., 4 p.

1195. Thatcher, R. C., J. L. Searcy, J. E. Coster, and G. D. Hertel, eds. [1981]. The southern pine beetle. U.S. Dep. Agric. For. Serv. and Sci. and Educ. Admin. Tech. Bull. 1631, 266 p.

1196. Thatcher, T. O. 1961. Forest entomology. 225 p. Burgess Publ. Co., Minneapolis, Minn.

1197. Thomas, H. A. 1969. Quantitative bioassay used to study inhibitory effects of two organotins in pales weevil feeding. U.S. Dep. Agric. For. Serv., Res. Note SE-118, 266 p. Southeast. For. Exp. Stn., Asheville, N.C.

1198. Thomas, H. A. 1971. Integrated control of weevils attacking coniferous reproduction. J. For. 69:806-808.

1199. Thomas, H. A., J. H. Ghent, and C. G. Stone. 1982. Use of pheromone traps as a new technique in a large-scale survey of the introduced pine sawfly (Hymenoptera: Diprionidae). Bull. Entomol. Soc. Am. 28:303-304.

1200. Thomas, J. B., and H. Herdy. 1961. A note on the life history

of *Cimberis elongatus* (LeC.) (Coleoptera: Anthribidae). Can. Entomol. 93(5):406-408.

1201. Thompson, H. E., and J. G. Matthysse. 1972. Role of the native elm bark beetle, *Hylurgopinus rufipes* (Eichh.), in transmission of the Dutch elm disease pathogen, *Ceratocystis ulmi* (Buisman) C. Moreau. N.Y. State Agric. Exp. Stn., Search Agric. [Replaces Bull. Ser.] 2(1):1-16.

1202. Thompson, L. C., and H. M. Kulman. 1980. Parasites of the yellowheaded spruce sawfly, *Pikonema alaskensis* (Hymenoptera: Tenthredinidae), in Maine and Nova Scotia. Can. Entomol. 112:25-29.

1203. Thompson, W. R. 1956. The fundamental theory of natural and biological control. Annu. Rev. Entomol. 1:379-402.

1204. Tietz, H. M. 1972. An index to the described life histories, early stages and hosts of the Macrolepidoptera of the continental United States and Canada. vol. 1, p. 1-536; vol. 2, p. 537-1041. Publ. by A. C. Allyn for Allyn Mus. Entomol., Sarasota, Fla.

1205. Tippins, H. H., ed. 1982. A review of information on the lesser cornstalk borer, *Elasmopalpus lignosellus* (Zeller). Univ. Ga. Coll. Agric. Exp. Stn. Spec. Publ. 17, 65 p. Griffen, Ga.

1206. Torgersen, T. R. 1964. The bionomics of the European pine shoot moth, *Rhyacionia buoliana* (Schiffermüller) (Lepiodoptera: Tortricidae), in Wisconsin. Ph.D. Diss., Univ. Wis. 237 p.

1207. Tothill, J. D. 1922. The natural control of the fall webworm (*Hyphantria cunea* Drury) in Canada: together with an account of its several parasites. Dom. Can. Dep. Agric. Bull. (n.s.) 3 (Tech.), p. 1-107. Ottawa.

1208. Townes, H. 1958. Some biological characteristics of the Ichneumonidae (Hymenoptera) in relation to biological control. J. Econ. Entomol. 51(5):650-652.

1209. Triplehorn, C. A. 1955. The Asiatic oak weevil in Delaware. J. Econ. Entomol. 48(3): 289-293.

1210. Tripp, H. A. 1954. Description and habits of the spruce seedworm, (*Laspeyresia youngana* (Kft.) (Lepidoptera: Olethreutidae). Can. Entomol. 86(9):385-402.

1211. Tripp, H. A. 1962. The biology of *Perilampus hyalinus* Say (Hymenoptera: Perilampidae), a primary parasite of *Neodiprion swainei* Midd. (Hymenoptera: Diprionidae) in Quebec, with descriptions of the egg and larval stages. Can. Entomol. 94(12):1250-1270.

1212. Turnbow, R. H., Jr., and R. T. Franklin. 1981. Bionomics of *Brachys tessellatus* in Coastal Plain scrub oak communities. Ann. Entomol. Soc. Am. 74:351-358.

1213. Turnbull, A. L., and D. A. Chant. 1961. The practice and theory of biological control of insects in Canada. Can. J. Zool. 39(5):697-753.

1214. Turnipseed, G. F., and C. F. Smith. 1953. Life history and control of scales on apples in North Carolina. J. Econ. Entomol. 46(6):969-972.

1215. Turnock, W. J. 1953. Some aspects of the life history and ecology of the pitch nodule maker, *Petrova albicapitana* (Busck) (Lepidoptera—Olethreutidae). Can. Entomol. 85(7):233-243.

1216. Turnock, W. J., and J. A. Muldrew. 1971. *Pristiphora erichsonii* (Hartig), larch sawfly (Hymenoptera: Tenthredinidae). *In* Biological control programmes against insects and weeds in Canada. Commonw. Inst. Biol. Control., Agric. Bur. Tech. Commun. 4, p. 175-194.

[Commonw. Agric. Bur., Farnham Royal, Slough, England.]
1217. Underwood, G. R., and F. A. Titus. 1968. Description and seasonal history of a leaf miner on poplar *Messa populifoliella* (Hymenoptera: Tenthredinidae). Can. Entomol. 100:407-411.
1218. U.S. Department of Agriculture. 1967. Oriental wood borer *(Heterobostrychus aequalis* (Waterhouse)). U.S. Dep. Agric. Coop. Econ. Insect Rep. 17(7):95.
1219. U.S. Department of Agriculture, Entomology Research Division, Agricultural Research Service. 1963. Wood ticks: How to control them in infested places. U.S. Dep. Agric. Leafl. 387 rev.
1220. U.S. Department of Agriculture, Entomology Research Division, Agricultural Research Service. 1966. Periodical cicadas. U.S. Dep. Agric. Leafl. 540, 8 p.
1221. U.S. Department of Agriculture, Forest Service. 1958. Timber resources for America's future. U.S. Dep. Agric. For. Serv., For. Resour. Rep. 14, 713 p.
1222. U.S. Department of Agriculture, Forest Service. 1979. A guide to common insects and diseases of forest trees in the northeastern United States. U.S. Dep. Agric. For. Serv., Northeast. Area State & Priv. For., For. Insect & Dis. Manage. Publ. NA-FR-4, 127 p. Broomall, Pa.
1223. U.S. Department of Agriculture, Forest Service, Division of Forest Insect Research. 1964. The elm leaf beetle. U.S. Dep. Agric. For. Serv. Leafl. 184 rev., 4 p. [Originally issued 1939 (C. W. Collins, author).]
1224. U.S. Department of Agriculture, Forest Service, Division of Forest Insect Research. 1965. Cankerworms. U.S. Dep. Agric. Leafl. 183 rev., 8 p. [Originally issued 1939 (T. H. Jones, author) and in 1953 by Div. For. Insect., Bur. Entomol. & Plant Quar., Agric. Res. Admin.]
1225. U.S. Environmental Protection Agency. 1976. The federal insecticide, fungicide, and rodenticide act as amended. 22 p. Washington, D.C.
1226. Uvarov, B. P. 1928. Locusts and grasshoppers: A handbook for their study and control. 352 p. Imp. Bur. Entomol., London.
1227. Valentine, B. D. 1960. The genera of the weevil family Anthribidae north of Mexico (Coleoptera). Trans. Am. Entomol. Soc. 86(1):41-85.
1228. Van Derwerker, G. K., and H. M. Kulman. 1974. Stadium and sex determination of yellowheaded spruce sawfly larvae, *Pikonema alaskensis*. Ann. Entomol. Soc. Am. 67:29-31.
1229. Van Duzee, E. P. 1923. Family Fulgoridae. *In* Guide to the insects of Connecticut. Part IV. The Hemiptera or sucking insects of Connecticut. W. E. Britton. State of Conn., State Geol. & Nat. Hist. Surv. Bull. 34, p. 24-55.
1230. Van Leeuwen, E. R. 1952. Life history and habits of the chestnut weevils. J. Econ. Entomol. 45(6):1089-1091.
1231. Verrall, A. F. 1941. Dissemination of fungi that stain logs and lumber. J. Agric. Res. 63(9): 549-558.
1232. Verrall, A. F. 1943. Fungi associated with certain ambrosia beetles. J. Agric. Res. 66(3): 135-144.
1233. Vité, J. P. 1970. Pest management systems using synthetic pheromones. Symposium on population attractants. Contrib. Boyce Thompson Inst. 24: 343-350.
1234. Volnay, W. J. A. 1979. Estimat-

ing epidemic populations of the lesser maple spanworm (Lepidoptera: Geometridae). Can. Entomol. 111:189-200.

1235. Wade, O. 1917. The sycamore lace-bug: *(Corythucha ciliata* (Say)). Okla. Agric. & Mech. Coll., Agric. Exp. Stn. Bull. 116, 16 p.

1236. Wagner, T. L., and D. E. Leonard. 1980. Mortality factors of satin moth, *Leucoma salicis* (Lep.: Lymantriidae), in aspen forests in Maine. Entomophaga 25:7-16.

1237. Walgenbach, D. D., and D. M. Benjamin. 1964. Biology of the pine tussock moth. Proc. North Cent. Branch, Entomol. Soc. Am. 19:21-22.

1238. Walker, T. J. 1973. Systematics and acoustic behavior of United States and Carribbean short-tailed crickets (Orthoptera: Gryllidae: *Anurogryllus).* Ann. Entomol. Soc. Am. 66: 1269-1277.

1239. Wallace, P. P. 1945. Biology and control of the dogwood borer, *Synanthedon scitula*. Conn. Agric. Exp. Stn. Bull. 488, p. 373-395.

1240. Wallesz, D. P., and D. M. Benjamin. 1960. The biology of the pine webworm, *Tetralopha robustella*, in Wisconsin. J. Econ. Entomol. 53(4):587-589.

1241. Wallner, W. E. 1966. Insects affecting woody ornamental shrubs and trees. Mich. State Univ. Ext. Bull. 530, p. 39.

1242. Walstad, J. D., and J. C. Nord. 1975. Applied aspects of pales weevil control. Down to Earth 31:8-12.

1243. Walton, B. C. J. 1960. The life cycle of the hackberry gall-former, *Pachypsylla celtidisgemma* (Homoptera: Psyllidae). Ann. Entomol. Soc. Am. 53(2): 265-277.

1244. Wargo, P. M. 1977. *Armillariella mellea* and *Agrilus bilineatus* and mortality of defoliated oak trees. For. Sci. 23:485-492.

1245. Wargo, P. M. 1981. Defoliation and tree growth. *In* The gypsy moth: research toward integrated pest management. C. C. Doane and M. L. McManus, eds. U.S. Dep. Agric. For. Serv., Sci. and Educ. Agency, and Anim. and Plant Health Insp. Serv. Tech. Bull. 1584, p. 225-240.

1246. Wargo, P. M. 1981. Defoliation, dieback, and mortality. *In* The gypsy moth: research toward integrated pest management. C. C. Doane and M. L. McManus, eds. U.S. Dep. Agric. For. Serv., Sci. and Educ. Agency, and Anim. and Plant Health Insp. Serv. Tech. Bull. 1584, p. 240-248.

1247. Warner, R. E. 1966. A review of the *Hylobius* of North America with a new species injurious to slash pine (Coleoptera: Curculionidae). Coleopt. Bull. 20(3):65-81.

1248. Warner, R. E. 1975. New synonymy, key and distribution of *Graphognathus*, white fringed beetles (Coleoptera: Curculionidae), in North America. U.S. Dep. Agric., Coop. Econ. Insect Rep. 25, p. 855-860. Washington, D.C.

1249. Warner, R. E. 1975. The genus *Otiorhynchus* in America north of Mexico (Coleoptera: Curculionidae). Proc. Entomol. Soc. Wash. 78:240-262.

1250. Warren, G. L. 1960. External anatomy of the adult of *Hylobius warreni* Wood (Coleoptera: Curculionidae) and comparison with *H. pinicola* (Couper). Can. Entomol. 92(5):321-341.

1251. Warren, L. O., and J. F. Coyne. 1958. The pine sawfly—*Neodiprion taedae linearis* Ross—in Arkansas. Ark. Agric. Exp. Stn. Bull. 602, 23 p.

1252. Waters, D. J. 1981. Life history of *Neoclytus acuminatus* with notes on other cerambycids as-

sociated with dead and dying deciduous trees. M.S. Thesis. Dep. Entomol., Auburn Univ., Auburn, Ala. 103 p.

1253. Waters, W. E. 1955. Sequential sampling in forest insect surveys. For. Sci. 1(1):68-79.

1254. Waters, W. E., T. McIntyre, and D. Crosby. 1955. Loss in volume of white pine in New Hampshire caused by the white-pine weevil. J. For. 53(4): 271-274.

1255. Watson, W. Y., G. R. Underwood, and J. Reid. 1960. Notes on *Matsucoccus macrocicatrices* Richards (Homoptera: Margarodidae) and its association with *Septobasidium pinicola* Snell in eastern Canada. Can. Entomol. 92(9): 662-667.

1256. Wear, J. F., and J. W. Bongberg. 1951. Use of aerial photographs in forest insect surveys. J. For. 49(9):632-633.

1257. Wear, J. F., R. B. Pope, and P. W. Orr. 1966. Aerial photographic techniques for estimating damage by insects in western forests. 79 p. U.S. Dep. Agric. For. Serv., Pacific Northwest For. & Range Exp. Stn., Portland, Oreg. [Unnumbered publication.]

1258. Weaver, J. E., and C. K. Dorsey. 1965. Parasites and predators associated with five species of leaf-mining insects in black locust. Ann. Entomol. Soc. Am. 58(6):933-934.

1259. Weaver, J. E., and R. A. Sommers. 1969. Life history and habits of the short-tailed cricket, *Anurogryllus muticus*, in central Louisiana. Ann. Entomol. Soc. Am. 62(2):337-342.

1260. Webb, F. E., and R. S. Forbes. 1951. Notes on the biology of *Pleroneura borealis* Felt (Xyelidae: Hymenoptera). Can. Entomol. 83(7):181-183.

1261. Webb, J. L. 1909. Some insects injurious to forests. The southern pine sawyer (*Monohammus titillator* Fab.). U.S. Dep. Agric. Bur. Entomol., Part 4, Bull. 58, p. 41-56.

1262. Webber, R. T., and J. V. Schaffner, Jr. 1926. Host relations of *Compsilura concinnata* Meigen, an important tachinid parasite of the gipsy moth and brown-tail moth. U.S. Dep. Agric. Bull. 1363, 31 p.

1263. Weber, R. G., and M. V. Holman. 1976. *Coleomegilla maculata* (De Geer), (Coleoptera: Coccinellidae), a new coleopteran predator of the elm leaf beetle, *Pyrrhalta luteola* (Mueller), (Coleoptera: Chrysomelidae). J. Kans. Entomol. Soc. 49(2):160.

1264. Weber, R. G., and H. E. Thompson. 1976. Oviposition site characteristics of the elm leaf beetle, *Pyrrhalta (Galerucella) luteola* (Mueller) in north-central Kansas (Coleoptera: Chrysomelidae). J. Kans. Entomol. Soc. 49(2):171-176.

1265. Webster, J. M., and J. F. Bronskill. 1968. Use of Gelgard M and an evaporation retardant to facilitate control of the larch sawfly by a nematode-bacterium complex. J. Econ. Entomol. 61:1370-1373.

1266. Weesner, F. M. 1965. The termites of the United States: a handbook. 70 p. Natl. Pest Control Assoc., Elizabeth, N.J.

1267. Weesner, F. M. 1970. Termites of the Nearctic region. *In* Biology of termites, vol. 2. p. 477-525. K. Krishna and F. M. Weesner, eds. Academic Press, New York and London.

1268. Weidhaas, J. A., Jr., and F. R. Shaw. 1956. Control of the taxus mealybug with notes on its biology. J. Econ. Entomol. 49(2):273-274.

1269. Weiss, F., and R. A. St. George. 1959. Culture, diseases, and pests of the box tree. U.S. Dep. Agric., Farmers'

Bull. 1855 rev., 21 p.
1270. Welch, H. E. 1963. Nematode infections. *In* Insect pathology, an advanced treatise, vol. 2. p. 363-392. E. A. Steinhaus, ed. Academic Press, New York and London.
1271. Wellington, W. G., J. J. Fettes, K. B. Turner, and R. M. Belyea. 1950. Physical and biological indicators of the development of outbreaks of the spruce budworm. Can. J. Res. 28:308-311.
1272. Werner, F. G., Chairman. 1982. Common names of insects and related organisms 1982. 132 p. Entomol. Soc. Am., College Park, Md.
1273. Werner, R. A. 1972. Systemic insecticidal action of disulfoton and Monitor® in loblolly pine seedlings. J. Ga. Entomol. Soc. 7(1):67-73.
1274. Werner, R. A. 1977. Biology and behavior of the spear-marked black moth, *Rheumaptera hastata* in interior Alaska. Ann. Entomol. Soc. Am. 70:328-336.
1275. Westcott, C. 1973. The gardener's bug book. 4th ed. 689 p. Doubleday & Co., Inc., Garden City, N.Y.
1276. Wester, H. V., and R. A. St. George. 1947. Life history and control of the webworm, *Homadaula albizziae*. J. Econ. Entomol. 40(4):546-553.
1277. Westveld, M. 1946. Forest management as a means of controlling the spruce budworm. J. For. 44(11):949-953.
1278. Westveld, M. 1954. A budworm vigor-resistance classification for spruce and balsam fir. J. For. 52(1):11-24.
1279. Wetzel, B. W., H. M. Kulman, and J. A. Witter. 1973. Effects of cold temperatures on hatching of the forest tent caterpillar *Malacosoma disstria* (Lepidoptera: Lasiocampidae). Can. Entomol. 105:1145-1149.
1280. Wheeler, A. G., Jr. 1980. Life history of *Plagiognathus albatus* (Hemiptera: Miridae), with a description of the fifth instar. Ann. Entomol. Soc. Am. 73:354-356.
1281. Wheeler, A. G., Jr., and T. J. Henry. 1976. Biology of the honeylocust plant bug, *Diaphnocoris chlorionis*, and other mirids associated with ornamental honeylocust. Ann. Entomol. Soc. Am. 69(6): 1095-1104.
1282. Wheeler, W. M. 1910. Ants: their structure, development and behavior. 663 p. Columbia Univ. Press, New York.
1283. White, R. E. 1962. The Anobiidae of Ohio (Coleoptera). Ohio Biol. Surv. Bull. (n.s.) 1(4):1-58.
1284. White, R. E. 1971. Key to North American genera of Anobiidae, with phylogenetic and synonymic notes (Coleoptera). Ann. Entomol. Soc. Am. 64(1):179-191.
1285. White, R. E. 1973. New North American *Euvrilletta* and *Xyletinus* with keys to species (Coleoptera: Anobiidae). J. Wash. Acad. Sci. 63(2):76-81.
1286. White, W. B., W. H. McLane, and N. F. Schneeberger. 1981. Pesticides. *In* The gypsy moth: research toward integrated pest management. Charles C. Doane and Michael L. McManus, eds. U.S. Dep. Agric. For. Serv., Sci. and Educ. Agency, and Anim. and Plant Health Insp. Serv. Tech. Bull. 1584, p. 420-442.
1287. Whitten, R. R., and R. U. Swingle. 1964. The Dutch elm disease and its control. U.S. Dep. Agric., Inf. Bull. 193 rev., 12 p.
1288. Wickman, B. E. 1963. The large aspen tortrix, *Choristoneura conflictana*, in California (Lepidoptera: Tortricidae). J. Econ. Entomol. 56:593-596.
1289. Wilcox, J. A. 1954. Leaf beetles

of Ohio (Chrysomelidae: Coleoptera). Ohio State Univ. Stud., Ohio Biol. Surv. Bull. 43. 8(3):353-506.

1290. Wilford, B. H. 1937. The spruce gall aphid *(Adelges abietis* Linnaeus) in southern Michigan. Univ. Mich. Sch. For. & Conserv. Circ. 2, 35 p.

1291. Wilford, B. H. 1940. The seedcorn maggot, a pest of red cedar seedlings. J. For. 38(8):658-659.

1292. Wilkinson, R. C. 1964. Development in *Neodiprion excitans* Rohwer as related to oviposition and pine needle growth. Can. Entomol. 96(8):1142-1147.

1293. Wilkinson, R. C. 1969. Control of the redheaded pine sawfly. IFAS, Univ. Fla., Sunshine State Agric. Res. Rep. (Nov.):13-15.

1294. Wilkinson, R. C. 1971. Slashpine sawfly, *Neodiprion merkeli*. 1. Oviposition pattern and descriptions of egg, female larva, pupa, and cocoon. Ann. Entomol. Soc. Am. 64(1): 241-247.

1295. Wilkinson, R. C., G. C. Becker, and D. M. Benjamin. 1966. The biology of *Neodiprion rugifrons* (Hymenoptera: Diprionidae), a sawfly infesting jack pine in Wisconsin. Ann. Entomol. Soc. Am. 59(4):786-792.

1296. Wilkinson, R. C., A. H. Chappelka III, M. E. Kraemer, H. C. Coppel, and F. Matsumura. 1982. Field responses of redheaded pine sawfly males to a synthetic pheromone and virgin females in Florida. J. Chem. Ecol. 8:471-475.

1297. Wilkinson, R. C., and A. T. Drooz. 1979. Oviposition, fecundity, and parasites of *Neodiprion excitans* from Belize, C. A. Environ. Entomol. 8:501-505.

1298. Williams, L. H. 1973. Anobiid beetles should be controlled. Pest Control 41(6):18,20, 22,38,40,42,44.

1299. Williams, L. H. 1973. Identifying wood-destroying beetles. Pest Control 41(5):30,32, 34,36,38,40.

1300. Williams, L. H. 1973. Recognition and control of wood destroying beetles. Pest Control 41(2):24,26,28.

1301. Williams, L. H. 1977. Responses of *Xyletinus peltatus* (Harris) (Coleoptera: Anobiidae) larvae to favorable and unfavorable temperatures. Mater. und Org. 12:59-67.

1302. Williams, L. H. 1980. Changes in wood processing and use have influenced the likelihood of beetle infestations in seasoned wood. U.S. Dep. Agric. For. Serv., Gen. Tech. Rep. SO-28, 10 p. South. For. Exp. Stn., New Orleans, La.

1303. Williams, L. H., and H. M. Barnes. 1979. How *Xyletinus peltatus* beetles affect strength of southern pine floor joists. Environ. Entomol. 8(2):304-306.

1304. Williams, L. H., H. M. Barnes, and H. O. Yates III. 1979. Beetle *(Xyletinus peltatus)* and parasite exit hole densities and beetle larval populations in southern pine floor joists. Environ. Entomol. 8(2):300-303.

1305. Williams, L. H., and H. R. Johnston. 1972. Controlling wood-destroying beetles in buildings and furniture. U.S. Dep. Agric. Leafl. 558, 8 p.

1306. Williams, L. H., and J. K. Mauldin. 1974. Anobiid beetle, *Xyletinus peltatus* (Coleoptera: Anobiidae), oviposition on various woods. Can. Entomol. 106(9):949-955.

1307. Williams, L. H., and J. K. Mauldin. 1981. Survival and growth of the anobiid beetle *Xyletinus peltatus* (Coleoptera: Anobiidae) on various woods. Can. Entomol. 113:651-657.

1308. Williams, L. H., and R. V. Smythe. 1978. Wood-destroying beetle treatment incidence in

Arkansas and Georgia during 1962 and 1967 with estimated losses caused by beetles for 11 southern states during 1970. U.S. Dep. Agric. For. Serv., Res. Pap. SO-143, 8 p. South. For. Exp. Stn., New Orleans, La.

1309. Williams, L. H., and J. D. Waldrop. 1978. *Xyletinus peltatus* seasonal flight, diel activity, and associated environmental influences. Ann. Entomol. Soc. Am. 71(4):567-574.

1310. Williams, M. L., and M. Kosztarab. 1972. The insects of Virginia—No. 5: Morphology and systematics of the Coccidae of Virginia with notes of their biology (Homoptera: Coccoidea). Va. Polytech. Inst. & State Univ., Res. Div. Bull. 74, 215 p.

1311. Williams, P. H. 1975. How Weyerhaeuser controls pales weevils—a pest of new pine forests. Ind. Veg. Manage. 7: 16-18.

1312. Williams, S. R., and R. A. Hefner. 1928. The millipedes and centipedes of Ohio. Ohio Biol. Surv. Bull. 18, 4(3): 91-147. [Also issued as Ohio State Univ. Bull., vol. 33(7).]

1313. Williston, S. W. 1908. Manual of North American Diptera. 3d ed. 405 p. J. T. Hathaway, New Haven, Conn.

1314. Willoughby, P. A., and M. Kosztarab. 1974. Studies on the morphology and systematics of scale insects—No. 7: Morphological and biological studies on two species of *Chionaspis* (Homoptera: Coccoidea: Diaspididae). Va. Polytech. Inst. & State Univ., Res. Div. Bull. 92, 8 p.

1315. Wilson, C. L., C. E. Seliskar, and C. R. Krause. 1972. Mycoplasmalike bodies associated with elm phloem necrosis. Phytopathology 62(1):140-143.

1316. Wilson, E. O. 1972. The insect societies. 548 p. The Belknap Press of the Harv. Univ. Press, Cambridge, Mass.

1317. Wilson, L. F. 1961. Grasshoppers—a major defoliator of trees and shrubs in the northern Great Plains. U.S. Dep. Agric. For. Serv., Lake States For. Exp. Stn., Tech. Notes 596, 2 p. [North Cent. For. Exp. Stn., St. Paul, Minn.]

1318. Wilson, L. F. 1961. Variable oak leaf caterpillar. U.S. Dep. Agric. For. Serv., For. Pest Leafl. 67, 4 p.

1319. Wilson, L. F. 1962. White-spotted sawyer. U.S. Dep. Agric. For. Serv., For. Pest Leafl. 74, 7 p.

1320. Wilson, L. F. 1962. Yellowheaded spruce sawfly. U.S. Dep. Agric. For. Serv., For. Pest Leafl. 69, 4 p.

1321. Wilson, L. F. 1963. The greenstriped mapleworm. U.S. Dep. Agric. For. Serv., For. Pest Leafl. 77, 4 p.

1322. Wilson, L. F. 1964. Walkingstick. U.S. Dep. Agric. For. Ser., For. Pest Leafl. 82, 4 p.

1323. Wilson, L. F. 1965. Life history and some habits of the pine gall weevil, *Podapion gallicola* Riley, in Michigan. Can. Entomol. 97(9):962-969.

1324. Wilson, L. F. 1966. Effects of different population levels of the European pine sawfly on young Scotch pine trees. J. Econ. Entomol. 59(5):1043-1049.

1325. Wilson, L. F. 1966. Introduced pine sawfly. U.S. Dep. Agric. For. Serv., For. Pest Leafl. 99, 4 p.

1326. Wilson, L. F. 1966. Life history, habits, and damage of the boxelder leaf gall midge, *Contarinia negundifolia* Felt (Diptera: Cecidomyiidae) in Michigan. Can. Entomol. 98(7): 777-784.

1327. Wilson, L. F. 1967. Effects of pruning and ground treatments on populations of the pine root

collar weevil. J. Econ. Entomol. 60(3):823-827.

1328. Wilson, L. F. 1968. Life history and habits of the willow beaked gall midge, *Mayetiola rigidae* (Diptera: Cecidomyiidae), in Michigan. Can. Entomol. 100(2):202-206.

1329. Wilson, L. F. 1968. Life history, habits, and damage of a gall midge, *Oligotrophus papyriferae* (Diptera: Cecidomyiidae), injurious to paper birch in Michigan. Can. Entomol. 100(6):663-669.

1330. Wilson, L. F. 1972. Life history and outbreaks of an oak leafroller, *Archips semiferanus* (Lepidoptera: Tortricidae), in Michigan. Great Lakes Entomol. 5:71-77.

1331. Wilson, L. F. 1973. Pruning and litter removal or soil scraping controls the pine root collar weevil in young red pine plantations. Environ. Entomol. 2:325-328.

1332. Wilson, L. F. 1975. Spatial and seasonal distribution of pine root collar weevil eggs in young red pine plantations. Great Lakes Entomol. 8:115-121.

1333. Wilson, L. F., 1977. A guide to insect injury of conifers in the Lake States. U.S. Dep. Agric., Agric. Handb. 501, 218 p.

1334. Wilson, L. F., and P. C. Kennedy. 1968. Suppression of the Saratoga spittlebug in the nymphal stage by granular Baygon®. J. Econ. Entomol. 61(3):839-840.

1335. Wilson, L. F., and I. Millers. 1966. Suppression of Saratoga spittlebug with helicopter application of low- and high-volume malathion. J. Econ. Entomol. 59(6):1456-1458.

1336. Wilson, L. F., and M. E. Ostry. 1980. How to identify and prevent injury by the poplar-gall Saperda. U.S. Dep. Agric., For. Serv. How-To Leafl., 6 p. North Cent. For. Exp. Stn., St. Paul, Minn.

1337. Wilson, L. F., and V. J. Rudolph. 1970. Early basal pruning to control forest pests. J. For. 68: 632-634.

1338. Wilson, L. F., and D. C. Schmiege. 1965. Pine root collar weevil. U.S. Dep. Agric. For. Serv., For. Pest Leafl. 39 rev., 7 p.

1339. Wilson, R. W., Jr., and G. A. Fontaine. 1978. Gypsy moth egg-mass sampling with fixed- and variable-radius plots. U.S. Dep. Agric., Agric. Handb. 523, 46 p.

1340. Wingfield, M. J., R. A. Blanchette, T. H. Nicholls, and K. Robbins. 1982. Pinewood nematode: a comparison of the situation in the United States and Japan. Can. J. For. Res. 12:71-75.

1341. Wirth, W. W. 1965. Family Ceratopogonidae (Heleidae). *In* A catalog of the Diptera of America north of Mexico. U.S. Dep. Agric., Agric. Handb. 276, p. 121-142.

1342. Wirth, W. W., Y. S. Sedman, and H. V. Weems, Jr. 1965. Family Syrphidae. *In* A catalog of the Diptera of America north of Mexico. U.S. Dep. Agric., Agric. Handb. 276, p. 557-625.

1343. Witter, J. A., and R. D. Fields. 1977. *Phyllobius oblongus* and *Sciaphillus asperatus* associated with sugar maple reproduction in northern Michigan. Environ. Entomol. 6:150-154.

1344. Witter, J. A., and H. M. Kulman. 1972. A review of the parasites and predators of tent caterpillars (*Malacosoma* spp.) in North America. Univ. Minn., Agric. Exp. Stn., Tech. Bull. 289, 48 p.

1345. Witter, J. A., and H. M. Kulman. 1979. The parasite complex of the forest tent caterpillar in northern Minnesota. Environ. Entomol. 8:723-731.

1346. Witter, J. A., H. M. Kulman,

and A. C. Hodson. 1972. Life tables for the forest tent caterpillar. Ann. Entomol. Soc. Am. 65(1):25-31.

1347. Witter, J. A., W. J. Mattson, and H. M. Kulman. 1975. Numerical analysis of a forest tent caterpillar (Lepidoptera: Lasiocampidae) outbreak in northern Minnesota. Can. Entomol. 107:837-854.

1348. Wolcott, G. N. 1914. Notes on the life history and ecology of *Tiphia inornata* Say. J. Econ. Entomol. 7(5):382-389.

1349. Wollerman, E. H. 1965. Bagworm. U.S. Dep. Agric. For. Serv., For. Pest Leafl. 97. 7 p.

1350. Wollerman, E. H. 1965. The boxelder bug. U.S. Dep. Agric. For Serv., For. Pest Leafl. 95, 6 p.

1351. Wollerman, E. H. 1962. The locust borer. U.S. Dep. Agric. For. Serv., For. Pest Leafl. 71, 7 p.

1352. Wollerman, E. H. 1970. The locust borer. U.S. Dep. Agric. For. Serv., For. Pest Leafl. 71 rev., 8 p.

1353. Wood, S. L. 1963. A revision of the bark beetle genus *Dendroctonus* Erichson (Coleoptera: Scolytidae). Great Basin Nat. 23(1-2):1-117.

1354. Wood, S. L. 1978. New synonymy and new species of American bark beetles (Coleoptera: Scolytidae). Great Basin Nat. 37(3):383-394.

1355. Wood, S. L. 1979. A catalog of the Coleoptera of America north of Mexico. Family: Platypodidae. U.S. Dep. Agric., Agric. Handb. 529, fasc. 141, 5 p.

1356. Wood, S. L. 1982. The bark and ambrosia beetles of North and Central America (Coleoptera: Scolytidae), a taxonomic monograph. Great Basin Nat. Mem. 6, 1359 p. Brigham Young Univ., Provo, Utah.

1357. Woods, W. C. 1917. The biology of the alder flea-beetle, *Altica bimarginata* Say. Maine Agric. Exp. Stn. Bull. 265, p. 249-284.

1358. Woodwell, G. M. 1961. The persistence of DDT in a forest soil. For. Sci. 7:194-196.

1359. Wray, D. L. 1963. Collembola of North America. Part I: Hypogastrurinae. J. Tenn. Acad. Sci. 38(3):101-104.

1360. Wright, C. G. 1959. The influence of several environmental factors on the development of the southern lyctus beetle, *Lyctus planicollis* Leconte. Ann. Entomol. Soc. Am. 52(5): 632-634.

1361. Wright, C. G. 1960. Biology of the southern lyctus beetle, *Lyctus planicollis*. Ann. Entomol. Soc. Am. 53(3):285-292.

1362. Wright, J. W., and W. J. Gabriel. 1959. Possibilities of breeding weevil-resistant white pine strains. U.S. Dep. Agric. For. Serv., Stn. Pap. 115, 35 p. Northeast. For. Exp. Stn., Broomall, Pa.

1363. Yates, H. O., III. 1967. Key to Nearctic parasites of the genus *Rhyacionia:* with species annotations. 127 p. U.S. Dep. Agric. For. Serv., Southeast. For. Exp. Stn., Asheville, N.C. [Unnumbered publication.]

1364. Yates, H. O., III. 1977. Seed orchard pest management strategies. Proc. 14th South. For. Tree Improv. Conf. p. 88-99.

1365. Yates, H. O., III, and B. H. Ebel. 1975. Lighttrapping and identifying *Dioryctria* that damage pine cones in northeastern Georgia (Lepidoptera: Phycitidae). J. Ga. Entomol. Soc. 10:78-86.

1366. Yates, H. O., III, N. A. Overgaard, and T. W. Koerber. 1981. Nantucket pine tip moth. U.S. Dep. Agric., For. Insect & Dis. Leafl. 70 rev., 7 p.

1367. Yearian, W. C., and L. O. Warren. 1964. Insects of pine cones

in Arkansas. J. Kans. Entomol. Soc. 37(3):259-264.

1368. Young, H. C., B. A. App, J. B. Gill, and H. S. Hollingsworth. 1950. White-fringed beetles and how to combat them. U.S. Dep. Agric. Circ. 850, 15 p.

1369. Yuasa, H. 1923. A classification of the larvae of the Tenthredinoidea: with fourteen plates. Ill. Biol. Monogr. 7(4):1-172.

1370. Zappe, M. P. 1921. Notes on the life history of a sawfly feeding on Austrian pine, *Itycorsia zappei*. Conn. Agric. Exp. Stn. Bull. 226, p. 179-182.

Common and Scientific Names of Host Plants

acacia	*Acacia*
sweet, See: huisache	
ailanthus	*Ailanthus altissima*
alder	*Alnus*
andromeda	*Andromeda*
apple	*Malus* spp.
apricot	*Prunus armeniaca*
arborvitae	*Thuja*
See also: white-cedar, northern	
aralia	*Aralia*
ardisia	*Ardisia*
ash	*Fraxinus*
black	*Fraxinus nigra*
European	*Fraxinus excelsior*
green	*Fraxinus pennsylvanica*
pumpkin	*Fraxinus profunda*
red, See: ash, pumpkin	
velvet	*Fraxinus velutina*
white	*Fraxinus americana*
aspen, See: poplar	
Australian-pine	
See: casuarina, horsetail	
azalea, See: rhododendron	
baldcypress	*Taxodium distichum*
bamboo	*Bambusa* spp.
banak	*Virola* spp.
banyan, See: fig, shortleaf	
basswood	*Tilia*
American	*Tilia americana*
bayberry	*Myrica*
beech	*Fagus*
American	*Fagus grandifolia*
European	*Fagus sylvatica*
oriental	*Fagus orientalis*
birch	*Betula*
European white	*Betula pendula*
gray	*Betula populifolia*
paper	*Betula papyrifera*
river	*Betula nigra*
sweet	*Betula lenta*
white, See: birch, paper	
yellow	*Betula alleghaniensis*

bittersweet	*Celastrus*
blackgum, See: tupelo	
blue-beech, See: hornbeam, American	
blueberry	*Vaccinium*
boxelder	*Acer negundo*
boxwood, European	*Buxus sempervirens*
Brazil nut tree	*Bertholletia excelsa*
buckeye	*Aesculus*
bumelia	*Bumelia* spp.
butternut	*Juglans cinerea*
camellia	*Camellia japonica*
camphor-tree	*Cinnamomum camphora*
cancer-root	*Conopholis americana*
caragana	*Caragana arborescens*
casuarina, horsetail	*Casuarina equisetifolia*
catalpa	*Catalpa* spp.
cedar	*Cedrus*
Atlas	*Cedrus atlantica*
deodar	*Cedrus deodara*
of Lebanon	*Cedrus libani*
See also: juniper; arborvitae; white-cedar, northern	
cherry	*Prunus*
black	*Prunus serotina*
chokecherry	*Prunus virginiana*
Japanese flowering	*Prunus serrulata*
pin	*Prunus pensylvanica*
sour	*Prunus cerasus*
wild, See: cherry, black	
chestnut	*Castanea*
American	*Castanea dentata*
Asiatic, See: chestnut, Chinese & Japanese	
Chinese	*Castanea mollissima*
Japanese	*Castanea crenata*
See also: chinquapin	
chinaberry	*Melia azedarach*
chinquapin	*Castanopsis* spp.
chokeberry	*Pyrus arbutifolia*
coffeetree, Kentucky	*Gymnocladus dioicus*
cotoneaster	*Cotoneaster pyracantha*
cottonwood	*Populus* spp.
See also: poplar	
crapemyrtle	*Lagerstroemia indica*
creeper, Virginia	*Parthenocissus quinquefolia*
cryptomeria	*Cryptomeria japonica*
cucumbertree	*Magnolia acuminata*
cypress	*Cupressus* spp.

dogwood	*Cornus* spp.
Douglas-fir	*Pseudotsuga menziesii*
elder	*Sambucus*
American	*Sambucus canadensis*
elm	*Ulmus*
American	*Ulmus americana*
Camperdown	*Ulmus glabra camperdownii*
cedar	*Ulmus crassifolia*
English	*Ulmus campestris*
European	*Ulmus effusa*
Japanese	*Ulmus japonica*
rock	*Ulmus thomasii*
Scotch	*Ulmus glabra*
September	*Ulmus serotina*
Siberian	*Ulmus pumila*
slippery	*Ulmus rubra*
euonymus	*Euonymus* spp.
fig	*Ficus*
shortleaf	*Ficus citrifolia*
fir	*Abies*
balsam	*Abies balsamea*
Fraser	*Abies fraseri*
Siberian	*Abies sibirica*
subalpine	*Abies lasiocarpa*
white	*Abies concolor*
forsythia	*Forsythia*
fremontia	*Fremontodendron*
fringetree	*Chionanthus virginicus*
gardenia	*Gardenia* spp.
ginkgo	*Ginkgo biloba*
gooseberry-tree	*Phyllanthus acidus*
grape	*Vitis* spp.
greenbrier	*Smilax laurifolia*
hackberry	*Celtis occidentalis*
netleaf	*Celtis reticulata*
hawthorn	*Crataegus* spp.
hazel	*Corylus*
hemlock	*Tsuga*
eastern	*Tsuga canadensis*
hickory	*Carya*
pignut	*Carya glabra*
holly	*Ilex*
American (typical)	*Ilex opaca* var. *opaca*
Chinese	*Ilex cornuta*
Japanese	*Ilex crenata*

honeylocust	*Gleditsia triacanthos*
hophornbeam	*Ostrya*
eastern	*Ostrya virginiana*
hops	*Humulus americanus*
hoptree	*Ptelea trifoliata*
hornbeam, American	*Carpinus caroliniana*
See also: hophornbeam	
horsechestnut, See: buckeye	
huckleberry	*Gaylussacia* spp.
huisache	*Acacia farnesiana*
incense-cedar	*Libocedrus decurrens*
ironwood, See: hornbeam, American	
Japan cedar, See: cryptomeria	
juniper	*Juniperus*
Ashe	*Juniperus ashei*
California	*Juniperus californica*
common	*Juniperus communis*
Irish	*Juniperus communis* var. *stricta*
oneseed	*Juniperus monosperma*
western	*Juniperus occidentalis*
larch	*Larix*
Dahurian	*Larix gmelini*
eastern	*Larix laricina*
European	*Larix decidua*
Japanese	*Larix leptolepis*
Siberian	*Larix sibirica*
subalpine	*Larix lyallii*
western	*Larix occidentalis*
laurel, See: mountain-laurel	
lilac	*Syringa vulgaris*
linden, See: basswood	
locust	*Robinia* spp.
black	*Robinia pseudoacacia*
luan/meranti	*Shorea* spp.
magnolia	*Magnolia* spp.
star	*Magnolia stellata*
See also: cucumbertree	
mahogany	*Swietenia mahagoni*
mahonia	*Mahonia* spp.
mangrove	*Rhizophora mangle*
maple	*Acer*
Japanese	*Acer palmatum*
mountain	*Acer spicatum*
Norway	*Acer platanoides*
planetree	*Acer pseudoplatanus*

red	*Acer rubrum*
silver	*Acer saccharinum*
sugar	*Acer saccharum*
See also: boxelder	
mesquite	*Prosopis*
mimosa	*Albizia julibrissin*
moss, Spanish	*Tillandsia usneoides*
mountain-ash	*Sorbus*
American	*Sorbus americana*
European	*Sorbus aucuparia*
hybrid	*Sorbaronia*
showy	*Sorbus decora*
mountain-laurel	*Kalmia latifolia*
mulberry	*Morus*
nettle	*Urtica*
oak	*Quercus*
black	*Quercus velutina*
blackjack	*Quercus marilandica*
bur	*Quercus macrocarpa*
Chapman	*Quercus chapmanii*
cherrybark	*Quercus falcata* var. *pagodifolia*
chestnut	*Quercus prinus*
laurel	*Quercus laurifolia*
live	*Quercus virginiana*
northern pin	*Quercus ellipsoidalis*
northern red	*Quercus rubra*
Nuttall	*Quercus nuttallii*
overcup	*Quercus lyrata*
pin	*Quercus palustris*
post	*Quercus stellata*
runner, See: oak, sand post & sand live	
sand live	*Quercus virginiana* var. *geminata*
sand post	*Quercus stellata* var. *margaretta*
scarlet	*Quercus coccinea*
scrub	*Quercus* spp.
southern red	*Quercus falcata*
swamp white	*Quercus bicolor*
turkey	*Quercus laevis*
water	*Quercus nigra*
white	*Quercus alba*
obeche	*Triplochiton scleroxylon*
oleander	*Nerium oleander*
olive	*Olea europaea*
orange, sour	*Citrus aurantium*
Osage-orange	*Maclura pomifera*

pachysandra	*Pachysandra* spp.
palm	Palmae family
Canary Island date	*Phoenix canariensis*
palmetto	*Sabal*
cabbage	*Sabal palmetto*
papaya	*Carica papaya*
pawpaw	*Asimina tribola*
peach	*Prunus persica*
pear	*Pyrus communis*
pecan	*Carya illinoensis*
persea	*Persea* spp.
persimmon	*Diospyros virginiana*
phylox	*Phylox* spp.
pieris	*Pieris* spp.
pine	*Pinus*
Austrian	*Pinus nigra*
Caribbean	*Pinus caribaea*
Chinese	*Pinus tabulaeformis*
Corsican	*Pinus nigra poiretiana*
eastern white	*Pinus strobus*
European black, See: pine, Austrian	
jack	*Pinus banksiana*
Japanese white	*Pinus parviflora*
Japanese black	*Pinus thunbergiana*
Japanese red	*Pinus densiflora*
loblolly	*Pinus taeda*
lodgepole	*Pinus contorta* var. *latifolia*
longleaf	*Pinus palustris*
mugho, See: pine, Swiss mountain	
pitch	*Pinus rigida*
pond	*Pinus serotina*
ponderosa	*Pinus ponderosa*
red	*Pinus resinosa*
sand	*Pinus clausa*
Choctawhatchee	*Pinus clausa* var. *immuginata*
Ocala	*Pinus clausa* var. *clausa*
Scotch	*Pinus sylvestris*
shortleaf	*Pinus echinata*
slash	*Pinus elliottii* var. *elliottii*
Sonderegger	*Pinus sondereggeri*
South Florida slash	*Pinus elliottii* var. *densa*
spruce	*Pinus glabra*
Swiss mountain	*Pinus mugo*
Table Mountain	*Pinus pungens*
Virginia	*Pinus virginiana*
white, See: pine, eastern white	
plane, London	*Platanus acerifolia*
planetree, See: sycamore	
pondcypress	*Taxodium distichum* var. *nutans*

plum	*Prunus* spp.
American	*Prunus americana*
poison-ivy	*Toxicodendron radicans*
poison-sumac	*Toxicodendron vernix*
poplar	*Populus*
balsam	*Populus balsamifera*
bigtooth	*Populus grandidentata*
Lombardy	*Populus nigra* var. *italica*
quaking	*Populus tremuloides*
See also: yellow-poplar	
prickly ash	*Zanthoxylum*
privet	*Ligustrum*
pyracantha	*Pyracantha*
See also: cotoneaster	
quince	*Cydonia oblonga*
rattan-vine	*Berchemia scandens*
redbud	*Cercis canadensis*
redcedar, eastern	*Juniperus virginiana*
See also: juniper	
redgum, See: sweetgum	
rhododendron	*Rhododendron* spp.
royalpalm, Florida	*Roystonea elata*
sassafras	*Sassafras albidum*
serviceberry	*Amelanchier* spp.
Siberian peashrub, See: caragana	
silktree, See: mimosa	
smilax, See: greenbrier	
sourgum, See: tupelo	
sourwood	*Oxydendrum arboreum*
spicebush	*Lindera benzoin*
spirea	*Spiraea*
spruce	*Picea*
black	*Picea mariana*
blue	*Picea pungens*
Colorado blue, See: spruce, blue	
Engelmann	*Picea engelmannii*
Norway	*Picea abies*
red	*Picea rubens*
Sitka	*Picea sitchensis*
white	*Picea glauca*
strawberry	*Fragaria*
sugarberry	*Celtis laevigata*
sumac	*Rhus* spp.
staghorn	*Rhus typhina*
sweetfern	*Myrica (Comptonia) aspleniifolia*
sweetgum	*Liquidambar styraciflua*

Index to Insects by Host Plants

This index should enable foresters and others not trained in entomology to identify many of the insects and related forms causing damage to particular species of trees or shrubs. Only those insects having definite host plants are included. The common names of insects, where known, are used; otherwise, the scientific names are given. Where applicable, the part of the host injured or destroyed is listed in the following categories: **foliage; bark, wood, or twigs; buds, shoots, or roots; flowers, seeds, or fruits.** The readily identifiable **sucking insects** are listed separately from the feeding categories because of their primarily oligophagous feeding habits. In addition, wood products is listed as a host.

B

C

Insect Index

This is an alphabetical listing of the insect species by both scientific and common names. Where there are multiple entries, the primary discussion is indicated by a **boldface** page number.

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